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MEASURES FOR THE IMPROVEMENT OF SAFETY IN ARMY AVIATION

by

Alex M. Aulkeoff, Barry G. King, Joann H. Langston,
Alan D. Morris and Cecil E. Phillips

15 September 1960

Prepared for the Flight Safety Foundation, Inc.
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SUMMARY

SCOPE

1. The emphasis of this study is directed toward methodology which will be useful in accident prevention research. The problem is approached through introduction of task element analysis to accident analysis and to airplane design; and through study of the broad civil aviation lightplane accident experience as a reference

FINDINGS

2. The information usually gathered from pilot, crew, and observers at the time of an accident is insufficient to permit a complete study of the accident causes through task element analysis. More complete information regarding pilot and crew performance at the time of an accident must be obtained to enable task element analysis of the accident.

3 Among the various landing procedures commonly used to avoid and recover from ground loops, the crab approach and the use of brakes were found to be most hazardous. The wing-low approach and the application of power to maintain directional control during roll-out were found to be more reliable procedures.

4. The study of civil aviation accidents reveals that 50% of all accidents involve pilots having less than 50 hours time in type. Current experience in type is the single most important factor in accident prevention.

5. Data from civil aviation accidents indicates that pilots with less than 50 hours time in type account for approximately 70% of ground-loop accidents on dry runways

CONCLUSIONS

6. Task element analysis facilitates improved understanding of aviation accidents by providing quantitative measures of the pilot's tasks and his ability to perform these tasks under emergency conditions. Techniques are proposed for incorporating task element analysis in routine accident investigation and analysis.

7. Studies of Army accident records should be performed to determine the influence of pilot experience on various types of accidents. The adequacy of training and proficiency in flight time should be evaluated on an economical basis by relating accident costs to the costs of training and flight operations.

8. Evaluation of cockpit arrangement, visibility provisions, control and instrumentation, early in the design stages of new types of aircraft under development for Army use, should be directed toward improvement in safety.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION

1.1 Among the many facets of aviation safety, one of the more crucial is the ability of the pilot to recognize and react to an emergency. It is important to know the specific task elements required of the pilot during each phase of normal and emergency flight, and the sequence and the times required for their performance. Such task element analysis must include detailed consideration of all sensory and motor activities and judgments. Although the workload imposed on the pilot during normal operations is generally compatible with safe operation, during periods of unusual operations or emergencies the workload may increase beyond his capabilities. In such periods some tasks are disregarded, resulting in an increased probability that critical conditions can develop before the pilot can recognize the emergency and take successful corrective action. Task element analysis is considered in Section II.

1.2 A study of civil aviation accidents is an effective method of supplementing Army aviation accident experience data. It provides a broad experimental control group for comparison with those present or contemplated Army missions which are essentially analogous to civil operations. To date, civil aviation's accident data contribute principally to fixed-wing airplanes, but future attention to civil helicopter operation may provide information of value. Of special interest in the analyses is the influence of pilot experience in type and the comparative accident experience of similar aircraft types with tail-wheel and nose-wheel landing gear. The study of civil aviation accidents is presented in Sections III and IV.

1.3 The use of task element analysis in the study of accidents leads to careful consideration of the design features of the aircraft that may

contribute to the cause and magnitude of the emergency and to limitations on the preventive and corrective procedures available to the pilot. Certain aircraft design considerations which stem from task element analysis are put forth in Section V.

1.4 Recommendations for future studies in accident prevention research, aircraft design and pilot training are presented in Section VI.

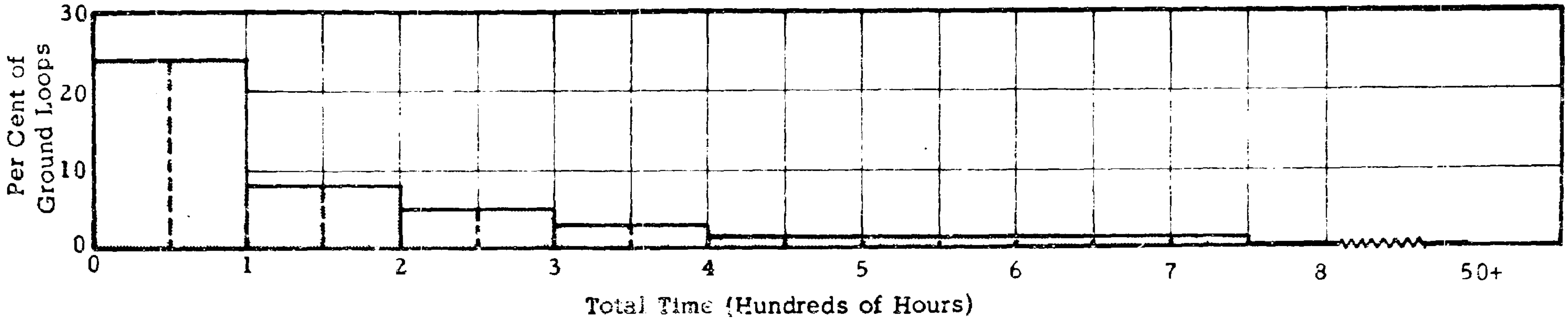
II. TASK ELEMENT ANALYSIS

2.1 It is important to know the specific tasks required of the pilot during each phase of normal and emergency flight, and the sequence and the times required for their performance. Such task analysis must include detailed consideration of all sensory and motor activities and judgment, as well as consideration of the kinetics of the accident situation. Although the workload imposed on the pilot during normal operations is generally compatible with safe operation, during periods of unusual operations or emergencies the workload may increase beyond his capabilities. In such periods some tasks are disregarded, resulting in an increased probability that critical conditions can develop before the pilot can recognize the emergency and take successful corrective action. In order to illustrate how task element analysis may be applied in practical accident analysis the ground-loop accident is considered in detail.

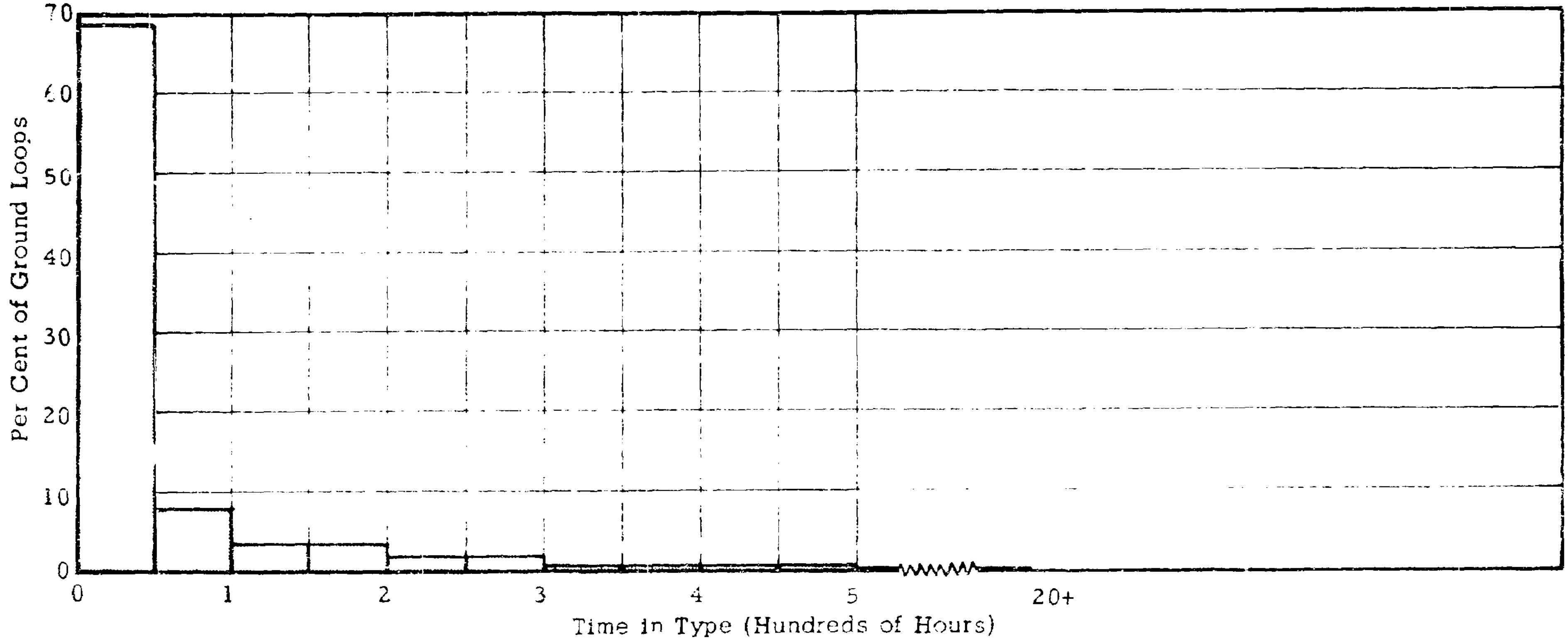
2.2 The problem of the ground loop is selected for particular emphasis because it is a phenomenon not well understood by many inexperienced pilots, and the preventive and corrective procedures for it are matters of controversy among experienced pilots and instructors. Attention is restricted to the L-19 tailwheel-type plane.

2.3 In this section comparisons are made between "experienced" and "inexperienced" pilots. The meaning of these terms is illustrated in Figures 1a and 1b, which are developed from data on civilian accidents.1/ The very high correlation evident between low flight-time pilots and ground-loop occurrence indicates that with regard to ground-loops, pilots may be considered "experienced" after 100 total hours or 50 hours in type.

1/ See Tables 1a and 2a, Appendix B.



1a. Incidence of 99 Ground Loops on Dry Runways as a Function of Pilot's Total Flying Time



1b. Incidence of 99 Ground Loops on Dry Runways as a Function of Pilot's Time in Type

FIGURE 1. RELATION OF PILOT EXPERIENCE TO INCIDENCE OF GROUND LOOPS

Kinetics of the Ground Loop

2.4 Because the location of the center of gravity in tailwheel airplanes is aft of the main landing gear, the vehicle is directionally unstable during landing roll-out. The vehicle responds to relatively mild lateral forces which tend to rotate the c.g. about the main gear to a position ahead of the main gear. These lateral forces may be of short duration, such as brief gusts of wind acting on the rudder, or uneven loads on the main gear caused by anomalies on the runway. After the initial lateral force is applied, the pivotal movement of the c.g. about the main gear induces an angular momentum involving the vehicle's total mass, which acts as though it were located entirely at the c.g.[2/] (Figure 2a).

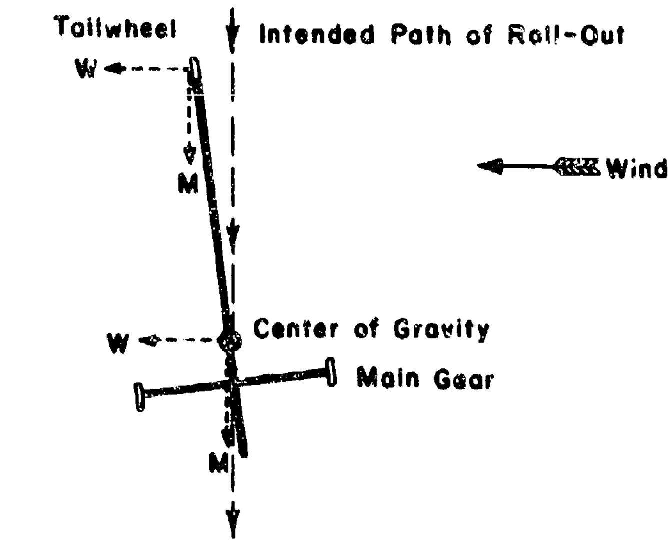
2.5 The initial lateral thrust also causes a change in the airplane's heading, which tends to cause a change in its actual path down the runway. The change in path is more likely to occur if the runway is dry and affords a high-friction surface. The tires tend to cause the plane to roll with the new heading rather than to slide or skid against it. However, it is characteristic of ground loops that both rolling and skidding occur. A turn without any skidding is indicative of mild forces and probably no loss of control by the pilot. Skidding by a tire not under braking action indicates at least some loss of control. The new path is the resultant of the forces acting in the direction of the new heading and the original forward momentum of the airplane (Figure 2b).

2.6 Due to the reduction in the forward momentum, the presence of the angular momentum and possibly continued lateral force from a crosswind, the new path of the airplane will be a curve. The curving path then induces a centrifugal force that acts on the c.g., increasing its angular momentum as it rotates about the main gear. The increased angular momentum causes a further change in heading, which induces more centrifugal force, which again increases the angular momentum.[3/]

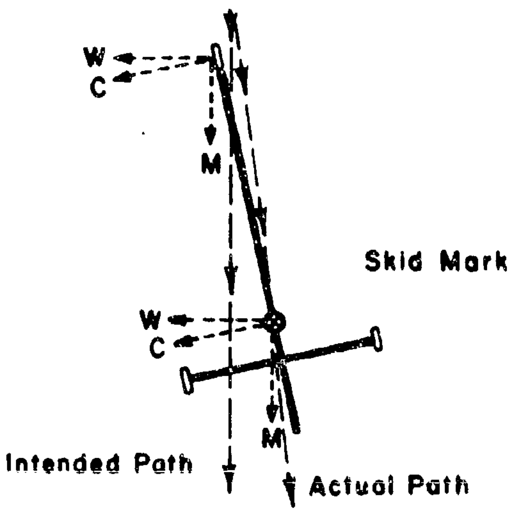
2.7 Brake action on one wheel may somewhat retard the angular movement. But, if the angular momentum has increased sufficiently, full braking action on one wheel will have no corrective effect on the ground loop. The difference between the heading and the actual path is also a factor in brake effectiveness, since the brake will tend to reduce the momentum in the heading direction only, not in the direction of the airplane's actual path. Thus the only effect of the braking action may be to cause the airplane to follow a shallow and longer curve before the final stage of the ground loop is reached.

2/ Neil D Van Sickle, (Ed.), Modern Airmanship, (Van Nostrand, Princeton, N.J : 1957), p. 338.

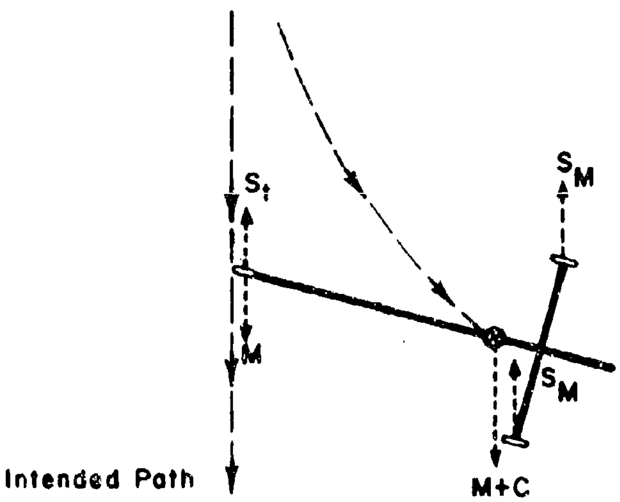
3/ Wolfgang Langewiesche, Stick and Rudder, (McGraw-Hill Book Co., Inc., New York: 1944), p. 314.



2a. Force of initial gust of wind W increases angular momentum M causing some angular displacement of aircraft's attitude.



2b. Change in direction of roll begins, adding centrifugal force C to the angular momentum already obtained. Tire marks begin. Force W may or may not continue to apply against the aircraft. At some point in this phase, depending on the various forces involved, a point of no correction is reached.



2c. Eventually the rotation progresses until the M and C vectors combine and fall "outside" the friction forces of the main gear, S_M. This combination of forces may act as a couple and produce a final rapid twisting action. Force S_t is too small to be significant. If S_M is large, as on a dry concrete runway, the landing gear may fail. If S_M is small, as on wet grass, the aircraft may continue rotating until a tail-first attitude is reached.

FIGURE 2. KINETICS OF THE GROUND LOOP

2.8 The final stage of the ground loop is reached when the c.g. has rotated to a point outside of the main gear, i.e., when the vehicle has rotated almost 90° from its original heading (Figure 2c). No force is then available to retard further rotation except the negligible frictional force at the tail wheel. Moreover, the frictional force of the main gear, which is now skidding sideways, creates a force opposite in direction of the momentum of the c.g.,; the combination of these two forces acts in the direction of rotation and results in a final rapid turn of the vehicle. The centrifugal force that develops often causes the vehicle to tip over on one wing.

Contributing Factors

2.9 Crosswind Approach Techniques. Ground loops often occur in the presence of a crosswind. Faulty crosswind approach technique is frequently the primary cause of the accident. A common mistake made by the inexperienced pilot is to allow the airplane to drift with the wind during final approach and touchdown. The side loads thus applied to the airplane through the landing gear tend to produce an immediate ground loop. This type of pilot error may be due to inadequate training, to lack of alertness, to fatigue, or to inadequate knowledge of wind conditions.

2.10 There are three methods of correcting for wind drift during landing. These are the wing-low, the crab, and the combination methods. The crab and combination approaches should be avoided, especially by novice pilots, for the following reasons:

a. The crab attitude must be eliminated just before touchdown. If this straightening maneuver is executed too early, the aircraft may drift with the wind and touch down with side loads on the landing gear. If the pilot is able to correct the drift by use of the wing-low method, this is an indication that the crab was not necessary in the first place. Or, if the straightening maneuver is attempted too late, there may not be time to fully accomplish it. The timing of the straightening action is a problem that invites error.

b. Associated with the proper timing of the straightening maneuver is the accuracy of the maneuver. Alignment with the runway during final approach is a difficult problem in flying, for the pilot must depend entirely on a number of visual clues, such as the relation between a selected aiming point and the

horizon, which are of a complex and variable nature.[4/] The crab attitude does not allow the pilot to see these clues in their normal perspective, thus making their interpretation more difficult. The problem is compounded at unfamiliar and unprepared fields where runway markings may be confusing or entirely lacking.

2.11 The wing-low approach to a large extent obviates the problems associated with the crab and combination approaches. Timing becomes less critical because the pilot may maintain the wing-low attitude through the moment of touchdown, if necessary, without undue hazard. The visual clues to runway alignment are also seen in a more nearly normal perspective.

2.12 There are situations in which the slipping effect of the wing-low attitude is inadequate to correct crosswing drift. In such cases the pilot must resort to a combination wing-low and crab attitude, correcting the crab before touchdown but maintaining the wing-low. However, there appears to be no justification for using the crab method alone.

2.13 Several other crosswind approach techniques are recommended by some pilots. These techniques include wheel landings, minimal or no use of flaps, and use of the extreme downwind side of the runway. The effects of these techniques are difficult to evaluate analytically. Experimentation does not appear to be justified because of the costs, dangers, and large number of other variables that would have to be controlled. However, Army accident reports and the USABAAR accident report filing system appear to be suitable for use in statistical tests on the relation of the various approach techniques and landing accidents. This type of study would be inexpensive, but the number of variables would still have to be dealt with, possibly by means of analysis of variance.

2.14 Runway Condition. The friction afforded by a dry, hard, runway surface can work to the pilot's disadvantage in an impending ground loop. Improper application of brakes to maintain directional control on a high-friction surface can result in a nose-up. Or, if a ground loop occurs, frictional forces acting on the wheels can cause the landing gear to fail or cause

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4/ Joseph W. Wulfeck, Vision in Military Aviation, WADC Technical Report 58-399, November, 1958.

the airplane to tip over onto a wing. On a low-friction surface, such as ice, wet grass, or even wet concrete, the frictional forces acting against the wheels are less likely to be dangerous. Of 106 ground loops analyzed by the CAB during a period of five months, 99 occurred on smooth, dry surfaces.

2.15 Pilot's Visibility During Roll-Out In tail-wheel airplanes, the pilot cannot see directly ahead of the airplane during roll-out in the three-point attitude. A result of this limitation is the lack of a clear directional reference, which increases the time needed to perceive a change in heading. Pilots attempt to compensate for this handicap by giving undivided attention to the visual references that are available.[5] The pilot strains forward in his seat as far as possible against the restraints imposed by the safety harness and the usual rearward position of the control stick during roll-out. He peers as nearly forward as possible, using some portion of the side of the fuselage as reference line to observe the heading.

2.16 The visibility restriction may contribute to the likelihood that a veer in the airplane's heading is detected too late for corrective action. Very little experimental data is available for testing this view. It is possible that the pilot's added concentration to overcome the visibility handicap is usually more than enough compensation and that the visual clues available are adequate for reliable directional control Pilots who are of shorter than average stature are especially handicapped by the restricted visibility in tail-wheel planes.[6] Research has indicated that in natural sitting position the eye level of approximately 95 per cent of pilots will lie between 27 and 34 inches above the seat cushion.[7] Whether these data have been taken into account by the aircraft manufacturer is not known. However, it would be desirable for the manufacturer to design cockpits in terms of characteristic distributions of the pilots' physical dimensions and make provisions for such adjustment of seat height as is necessary.

5/ W.H.B. Ellis and R.N. Allan, Pilot's Eye Movements During Visual Approaches and Landings, FPRC 888, Great Britain, September 1954. Also: T.M. Edwards and W.D. Howell, A Study of Pilots' Eye Movements During Visual Flight Conditions, CAA Indianapolis, January 1952.

6/ For example, see accident reports 00966 (L-19A), and 01950 (UIA), Board for Aviation Accident Research, Fort Rucker, Alabama.

7/ Barry G. King, "Functional Cockpit Design," Aeronautical Engineering Review, 11, 6, June 1952.

2.17 Reaction Time. When a potential ground loop begins, the pilot requires a certain time to recognize that a change in heading has occurred and to react to the situation. This reaction time imposes significant limitations on the corrective procedures available.

2.18 Research under laboratory conditions has shown that when a skilled pilot is concentrating only on changes in yaw he can perceive these changes and begin to correct them in 0.2 to 0.4 second, with the average time being 0.25 second.[8] It is reasonable to assume that under actual flight or roll-out conditions, when the pilot must attend to other flight functions, he would require approximately 0.5 second on the average to perceive a yaw movement and to initiate the proper response. The times required to complete the various responses, such as the application of full rudder, are also known. These latter times are used in the analyses of accidents included in this section.

Corrective Procedures

2.19 Rudder and Brake. One of the common procedures used to maintain directional control is to depend on the rudder action and, that failing, to apply heavy braking action to the wheel opposite the heading change. This procedure involves the following hazards:

1. The wheel under braking action may not be in effective contact with the ground, due to bouncing or to a one-wheel landing.
2. Over-correction and subsequent application of both brakes can cause a nose-up.
3. The airplane's momentum and the set of forces causing the impending ground loop can be sufficient to override the frictional force of full corrective braking action. This action becomes more likely as the ground loop progresses, because the braking force acts only in the direction opposite to the heading, not against the actual direction of travel.
4. If the rudder and then brakes are found to be ineffective or inadequate to regain control, there is little or no time remaining to attempt other corrective procedures.[9]

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[8] Donald C. Cheatham, A Study of the Characteristics of Human Pilot Control Response to Simulated Aircraft Lateral Motions, NACA Report 1197, Washington, D. C., 1954.

[9] See analysis of ground-loop accident, paragraphs 2.23—2.29.

2.20 Rudder and Throttle. Another procedure utilized to maintain directional control is to supplement the rudder action, when necessary, with brief application of power. This procedure has three principal disadvantages:

1. When an operator senses the impending loss of control of any vehicle, the usual reaction is to apply brakes rather than power.

2. If a ground loop has progressed too far, the application of power will have unpredictable and possibly dangerous results.

3. The distance needed for roll-out is increased.

If power is applied immediately upon sensing ineffectiveness of the rudder, the procedure provides the following advantages:

1. The propeller airstream, acting on the rudder, should be effective in correcting the airplane's heading

2. There is reduced danger of nose-up because the airstream increases stabilizer effectiveness in keeping the tail on the ground (assuming the stick is pulled back) and because the brakes are not applied.

3. The throttle may be applied about as quickly as the brake.[10]

2.21 Rudder and Stick. Some pilots believe that application of either brake or power is too dangerous. They rely on only the rudder and stick (holding the stick back and to the windward side) to maintain directional control. Information on the effectiveness of this procedure and the skill of the pilots who use it is not available.

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[10] To apply a brake, a left-right discrimination is required, then the foot must slide into position and the force applied. The average time required for this task is approximately 0.4 second. Since the left hand is always resting on the throttle, the average time required to move the throttle half its full stroke distance is approximately 0.2 second. (These times are obtained from synthetic standards in common use by industrial engineers. A reference is Ralph C. Barnes, Motion and Time Study, 4th ed., Wiley, New York, Chap. 28). The response time of the engine and of the airstream effect as compared with the response time of the brake mechanism is not known, making the comparison incomplete.

2.22 All Available Means. Another procedure for directional control is to use "all available means." This is usually interpreted as the following sequence of actions:

a. Application of rudder and stick.

b. Full application of brake.

c. Partial application of power

The fault with this procedure is that the application of power is regarded as a last resort. After rudder and then brakes have been tried, it is likely to be too late to apply power. This is pointed out under Rudder and Brake (paragraph 2.19) and is illustrated in the accident analysis to follow.

2.23 The application of power appears to be the most reliable emergency procedure. This procedure should be considered as the first step in maintaining directional control if the rudder alone proves inadequate. The natural reluctance of pilots to apply power can be eliminated through training. The possibility of a too late application of power is also reduced if pilots are trained to apply power immediately upon sensing an impending loss of control. If the power is added only briefly, just enough to blow the tail around to the correct heading, the increase in the roll-out distance will be small. The application of power is especially recommended for the early portion of the roll-out in which brake action is particularly dangerous. In the latter portion of the roll-out, where ground loops also occur, use of the brake instead of power may be desirable if short runway is a factor.

TASK ELEMENT ANALYSIS OF A GROUND LOOP ACCIDENT

2.24 The foregoing analysis of the ground loop is essential to the task element analysis procedure applied to the following ground loop accident.

Brief Description of Accident

USABAAR FILE NO. 01099

Aircraft:	L-19E, SN 56-2519	Pilot's Total Flying Time:	258
Place:	Las Vegas, Nevada	Date:	11 Dec 58
This Model:	Unknown	Time:	1630

2.25 On a cross-country training flight with a passenger, the pilot's flight plan called for a refueling stop at Las Vegas. Ten miles south of Las Vegas a report was received from Las Vegas radio to the effect that "weather conditions were normal." The pilot circled the field and selected the most

favorable runway according to the tetrahedron. Normal approach and touchdown were made. The airplane rolled 75-100 yards uneventfully and was "slowing to taxi speed." A veer to the right then occurred. The pilot applied left rudder and then left brake. As the veer continued, the left gear failed. The passenger attempted to apply partial throttle when the heading had changed approximately 90°. The aircraft came to rest after rotating 155° from the initial heading. Damages totaled $4,000. No injuries were incurred. The runway had a dry macadam surface.

Analysis of Investigating Board

2.26 It was determined that at the time of the accident there was a 19-knot crosswind at 40°. (The report does not indicate whether the pilot knew the magnitude of this wind.) The airplane traveled 157 feet after the tire marks began. The tire marks showed that the tail wheel was to the left of the main gear for the entire 157 feet. The board concluded that loss of directional control was the primary cause of the accident, with the crosswind being a contributing factor.

Additional Analysis

2.27 In order to make a more detailed analysis of the pilot's corrective procedures, it is necessary to estimate the speeds and time periods involved in the accident. From the known roll-out characteristics of the L-19, the fact that 75-100 yards of roll had been completed, and the passenger's comment that the airplane was "slowing to taxi speed" when the veer occurred, it is estimated that the plane's speed at the moment of the veer was 20-35 mph. A value of 30 mph (44 fps) is assumed.

2.28 It is further estimated that the last 157 feet of travel occurred in 3-5 seconds.

2.29 Now consider the pilot's reactions. In approximately 0.5 second after the initial veer he can begin to apply left rudder (see paragraph 2.17). The foot motion to apply the rudder requires approximately 0.4 second.[11/] The response time of the rudder control is not known, but it is assumed to be small enough to be neglected here. The pilot states that he then observed no recovery due to rudder application. The time for this observation is approximately the same as the time required for the initial perception, 0.5 second. The pilot then applied left brake, which requires 0.4 second.[12/] This

[11/] These time values are based on predetermined motion-time data. A reference is Ralph C. Barnes, Motion and Time Study, op. cit. In each case the minimum time value is estimated rather than the standard time, in order to account for the difference between normal and emergency procedures.

[12/] Ibid.

completed the pilot's attempt to regain control, and his total procedure may be summarized as follows:

0.5 second	-	perceive veer
0.4 "	-	apply rudder
0.5 "	-	observe effect
0.4 "	-	apply brake
1.8 "	-	total time required

2.30 Since the complete ground loop occurred in 3-5 seconds, the pilot's corrective procedure occupied 36-60% of this time. At some moment very close to the end of the ground loop the passenger applied partial throttle, but this action apparently had no effect.

2.31 It is possible that at some moment after the application of the brakes and before the passenger made the attempt to apply power, an application of power would have been effective in regaining control. However, after 1.8 seconds of uncontrolled turn, the heading of the airplane may have deviated too far for safe application of power. Certainly it is doubtful that the pilot could have known whether application of power would have been safe.

2.32 The sudden appearance of the tire marks (shown in the report photographs) indicates that the wind gust leading to the accident applied an impulsive, large lateral force on the vertical tail surface. This force caused the tail wheel to move outside the main gear very quickly. In such a sudden emergency, the pilot has sufficient reason to execute several corrective actions simultaneously, rather than try one at a time with observation periods between. If he had applied left rudder and throttle simultaneously, the time required for these actions would have been:

0.5 second	-	perceive veer
0.4 "	-	apply rudder and throttle
0.9 "	-	total time required

Simultaneous application of rudder and brake would have also required about 0.9 second (see footnote 10). The brake is less reliable and more dangerous than the throttle in the early phase of the ground loop. Thus we conclude that the pilot's chance of safe recovery would have been greatly enhanced if he had used the rudder-and-power method to regain control.

Summary of Ground Loop Accident Analysis

2.33 The essential features of the foregoing analysis are as follows:

a Conditions and procedures are considered normal to the moment the initial veer occurred.

b Once the emergency condition (the veer) presented itself, the following questions were considered:

(1) What corrective procedure did the pilot attempt to employ, and was it theoretically feasible to complete this procedure considering both the human factors and the time limit imposed by the impending accident? If the pilot followed a standard procedure, having a standard time requirement, part of this question could be answered easily. If neither standard procedures nor standard times existed (as in the case studied) the time required to complete the procedure must be estimated by other methods. The time limit imposed by the impending accident can only be determined by analysis of the kinetics of the particular case.

(2) If the pilot's corrective procedure was theoretically feasible, was the failure of the procedure due to the pilot's ineptness, or to extenuating circumstances such as poor aircraft maintenance, or to the inadequacy of the procedure in this instance?

c. With answers (or approximate answers) to the above questions, conclusions are drawn with regard to pilot training, emergency procedures, maintenance, and other factors pertinent to the accident type.

2.34 The critical portion of the analysis lies in the determination of the feasibility of the procedure used and the actual time limits imposed by the kinetics of the emergency. This analysis is usually made difficult by the lack of information regarding the distances, rates, and forces involved during the emergency condition. However, by careful consideration of the information that is available, and by emphasizing the details of the procedure used by the pilot and the kinetics of the emergency, it is sometimes possible, as in the above analysis of a ground loop, to obtain useful results.

TASK ELEMENT ANALYSIS OF A HELICOPTER ACCIDENT

2.35 As an example of what may be accomplished in cases affording even more limited information, consider the following helicopter accident and analysis.

Description

USABAAR FILE NO. 00764

Aircraft:	H-34A, SN 54-3047	Pilot's Total Flying time:	1195
Place:	Fort Rucker, Ala.	Date:	23 July 1958
This Model:	Unknown	Time:	1315

2.36 The pilot began a routine demonstration of an autorotative landing. Approach to the stage field was begun at 800-900 feet altitude, 60 knot airspeed and constant glide angle. Rate of descent was not known, but appeared to be normal (25 feet per second). Rotor RPM was also normal at 220, engine RPM was normal at 2200. At approximately 100 feet altitude, the pilot attempted a routine flare by pulling cyclic pitch. No response to this action was noted and the pilot, momentarily startled, pulled additional cyclic pitch. Still no response was observed, and the pilot believed that approximately two seconds had elapsed since first attempting the flare. Noting the then dangerously low altitude, the pilot applied collective pitch and power. The nose rose slightly just before the helicopter struck the ground. The helicopter skidded 350 feet and was subsequently consumed by fire. Investigators could not determine the cause of the accident, although failure of the cyclic control was suspected.

2.37 The recommended procedure for autorotative landings under emergency conditions calls for the flare to begin at only 40 to 50 feet. As is routine in practice, the pilot had allowed twice this altitude as a safety precaution. Nevertheless, when the cyclic control failed to operate and the pilot was momentarily startled, all other conditions apparently normal, there was insufficient time to recover. This indicates that the total time required to apply cyclic, observe the effect, and apply collective and power is at best only marginally compatible with the time allowed for this procedure during autorotative glide from 100 feet. In order to afford a safer time margin for practice autorotations, it may be advisable to train instructors to apply collective and power immediately upon observing an apparent malfunction of the controls, or to require that the flare be initiated at some altitude greater than 100 feet, or both.

2.38 In the above analysis, note that emphasis on the pilot's actions when faced with the emergency led to conclusions and recommendations not considered by the accident investigating board or USABAAR.

DATA COLLECTION AND ANALYSIS

2.39 In the foregoing sections emphasis has been placed on the fact that the value of accident analysis depends greatly upon the quantity and

quality of the pertinent data available The need for information on the pilot's actions and reactions and the kinetics of the emergency has received particular attention. Complete information regarding pilot and crew performance at the time of an accident must be obtained to enable task element analysis of the accident.

2.40 Study of a number of Army aircraft accident reports indicates that in many cases all available pertinent information was collected In many other cases one or more valuable items were not obtained in either the field surveys, the photographs, or in the interviews. The problem in data collection, therefore, is a matter of how to obtain consistency.

2.41 In order to obtain comprehensive data consistently in the field and in interviews it is desirable to use a standardized method of data gathering that is especially designed to include investigation into the facts involved in aircraft accidents. The use of a standardized form, similar in style to the one used by the Aviation Crash Injury Division of the Flight Safety Foundation, but emphasizing data pertinent to the cause of the accident, is one means of obtaining comprehensive information. The procedures listed in the Department of the Army PAM 95-5, "Handbook for Aircraft Accident Investigators," would provide a sound basis for the content of a standard form for investigation.[13/] Additional suggestions concerning the type of information most often omitted in routine investigations and methods that may be used to improve the consistency and reliability of accident investigations are listed below:

a. Diagrams and Photographs. The routine aerial photographs of accident sites are very helpful because they sometimes reveal information omitted in the recorded data. Often the sketches and diagrams are also valuable additions to the record. The use of photographs and especially dimensional diagrams should receive heavy emphasis in data collection. Diagrams should include not only measurements made at the impact area but also indications of intended flight path, point at which the emergency began, path of the aircraft during the emergency, and points at which particular elements of the recovery procedure were attempted, if known. The diagrams should include time and velocity scales, when known, in addition to the usual distance scale.

13/ The "General Checklist" from PAM 95-5 is shown in Appendix A.

This information aids greatly in analysis of the time available for receovery procedures, the acceleration (or deceleration) involved before the impact and other questions.

b. Distance. The distance, or altitude, traversed by an aircraft during an emergency is very important but often not recorded, even in some reports of ground loops. Together with airspeed, distance data provide the basis for estimates of time periods.

c. Pilot's Physical Dimensions The eye level of the pilot is especially important in questions of visibility. Arm length is also a significant factor in some cases.

d. Visibility. In addition to the pilot's eye level it is frequently desirable to know the condition of the windshield and structural and other possible limitations to visibility.

LIST OF TASK ELEMENTS

2.42 In addition to complete information gathered at the time of the accident, the accident analyst must have a comprehensive list of task elements for the aircraft With the aid of this list he can recreate the accident sequences, the pilot and crew actions. The development of such a satisfactorily detailed list would require instrumentation and research in the plane to determine the micromotions and times involved in each task element Some of the measurements of the human times could be made in simulators, although in this case the plane response time could not be known.

2.43 As an example of how a list of task elements may be prepared, studies were made of the normal tasks involved in flying the H-34A helicopter. The information was obtained largely by direct observation from the copilot's seat during practice flights. The comprehensive list, found in Appendix B, contains sections which describe the tasks involved in various segments of flight (take-off, climb cruise etc.). Thus the list is entitled "Flight Segment Analysis." To be complete, the Flight Segment Analysis must be expanded to show the breakdown of major time intervals into component times. This detailed breakdown will then be the analyst's aid in the reconstruction of accident situations or in determining possible flight areas where the pilot is overloaded.

Other Benefits of Task Element Analysis

2.44 Detailed studies of task elements provide not only measured data on the pilot's procedures but also afford a better understanding of the man-machine system as a whole. In particular, task element analysis enables quantitative evaluation of the functional utility of the machine's human engineering features. While it is true that the design of aircraft cockpits, controls and instruments with regard to human factors has received considerable emphasis in recent years, other engineering and production problems often result in the compromise of basic human engineering principles in the final design. For instance, as pointed out in Section V, the switches on the instrument panel of the H-34A are inconsistent with respect to labeling and to direction of operation. Consequently, it is necessary to continue to point out design deficiencies which have not been corrected to meet human requirements and to study new designs, arrangements and mock-ups to evaluate operational limitations imposed by the human factors in each new aircraft in order to obtain optimum results in the design and procurement of future aircraft, the training of pilots, and other aspects of Army aviation.

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III. CIVIL AVIATION LIGHT-PLANE ACCIDENT EXPERIENCE

3.1 The accidents which occur in civil aviation are well documented in the bimonthly accident analyses published by the Civil Aeronautics Board (CAB). The airplanes used in civil General Aviation[1/] are similar to Army airplanes. Many types of flight operations in civil aviation are comparable to the missions of Army aviation. Therefore, the accident experience of civil General Aviation serves as a good case for comparison with Army light-plane accident experience.

3.2 The planes used in Army aviation have these counterparts in General Aviation:

Army	Civilian
L-19	Cessna 170
L-20	De Havilland Beaver
L-23	Beechcraft Twin-Bonanza
L-26	Aero-Commander 520
U-1A	De Havilland Otter

1/ The term General Aviation includes all fixed-wind airplanes of under 12,500 lbs. gross weight, registered with the Federal Aviation Agency.

3.3 The operations in General Aviation parallel the missions of Army Aviation:

Mission	General Aviation	Army Aviation
Transportation	Business transportation Transportation for hire	Troop transport Light cargo transport Evacuation of casualties Rescue operations
Observation	Patrol Survey Search Civil Air Patrol	Surveillance Conduct of fire Air reconnaissance Column control Aerial photography Aerial survey operations
Communications		Radio relay Carrier service Visual signals
Pleasure	Personal pleasure	
Instruction	Dual and solo	Dual and solo
Special Operations	Aerial application Test, ferry, etc.	Light supply dropping Spraying and dusting wire laying

3.4 A survey conducted by the Federal Aviation Agency[2/] indicated the following breakdown for General Aviation flying·

[2/] Federal Aviation Agency, General Aviation Aircraft Use 1957, p. 1.

Type of Flying	Per Cent of Total
Business transportation	45
Pleasure and personal	19
Instruction, dual and solo	17
Aerial application	8
Transportation for hire	5
Patrol, survey and miscellaneous work	5
All other-test, ferry, etc.	1
Total	100

3.5 A comparison can be drawn for the fixed-wing, light-plane accident rate in Army Aviation and in General Aviation. The ratio of total Army Aviation hours flown in 1959 to the number of Army Aviation accidents in 1959 is:[3]

$$\frac{805{,}681 \text{ (Total Army Hours)}}{226 \text{ (Total Army Accidents)}} = 3560 \text{ Hours/Accident}$$

To evaluate the same ratio for General Aviation it is necessary to estimate the total hours flown in 1959, using the 1957 figure of total hours reported by the FAA,[4] and assuming the hours flown to be proportional to the total number of planes:

$$\frac{\text{Total Hours, 1959}}{68{,}727 \text{ (Total Planes, 1959)}} = \frac{10{,}938{,}000 \text{ (Total Hours, 1957)}}{66{,}520 \text{ (Total Planes, 1957)}} .$$

[3] U.S. Army, Active Army Accident Statistics, Calendar Year 1959. Army aircraft accidents are defined in A.R. 385-40, pp. 16-22. It is assumed that hours flown is a measure of exposure. This assumption, while recognized to be inadequate, is used for lack of a better criterion.

[4] General Aviation Aircraft Use 1957, op. cit. The CAB accident reports include those accidents which cause damage of one hundred dollars or more, or those accidents which cause less damage but involve unusual circumstances.

Then the estimated total General Aviation hours flown in 1959 is computed to be: 11,300,000. The ratio of total General Aviation hours flown in 1959 to the number of General Aviation accidents is:

$$\frac{11,300,000 \text{ (Total Hours)}}{4,726 \text{ (Total Accidents)}^{5/}} = 2490 \text{ Hours/Accident}$$

3.6 The CAB analyzes all accidents that occur in General Aviation.[6/] In addition to the bimonthly reports, CAB publishes the results of these analyses in a quantitative study of accidents for each calendar year. The most recent publication covers the calendar year 1958.[7/] The CAB is presently converting the information covered in the accident reports to an IBM data processing system. This is expected to be completed by 1 January 1961.

3.7 Reports of all accidents analyzed by the CAB from 1 March 1960 through 31 July 1960 were selected for this control study because data for pilot time in type and total time were included in the CAB reports after 1 March 1960. Of the 1940 accidents analyzed by the CAB during that period, 1660 met the criteria of the study and were chosen as the accident sample. The CAB reports contain the following information:

a. Docket number: assigned by the CAB.

b. Location: of accident.

c. Aircraft: manufacturer and serial number.

d. Damage to aircraft: destroyed, substantial, minor, none.

e. Injury to crew and passengers: fatal, serious, minor, none.

f. Purpose of flight: business, pleasure, crop control, etc.

g. Probable cause: determined by the CAB.

5/ Preliminary CAB figures for 1959.

6/ From 1954-1958 the Federal Aviation Agency had responsibility for the light-plane accident reports. Effective 1 January 1959, the CAB maintains custody of these reports.

7/ General Aviation Accidents (Non-Air Carrier). A Statistical Analysis, Calendar Year 1958.

h. Summary: pilot's license, pilot's age, pilot's time in type and total time, time of accident, description of accident.

3.8 Those planes which were included in the sample had the following characteristics:

a. Fixed wing.

b. Under 12,000 lbs. gross weight.

c. Six or less places.

d. Land planes only.

Those accidents which happened to planes not fitting this set of characteristics were omitted. Accidents which occurred to unoccupied planes were omitted.

3.9 In order to make efficient use of the information conta ned in the CAB reports, a Key-Sort data processing system was used. This manual system, which is adequate for a sample of this size, utilizes a deck of punch cards with 100 numbered holes (Figure 3). Using a master code, a card was punched for each accident. Specific programs were devised to derive statistical data concerning the 1660 accidents in the sample. The statistical results in tabular form are shown in Appendix C.

<u>Punch Card Code</u>

1. Docket Number	Written in.
2. Plane Name	14 holes for popular models, e.g., Piper, Cessna, Beech etc., plus 1 for "other".
3. Total time	Pilot's total amount of flying time; 13 increasing intervals e.g., to 100, 101 to 200, etc.
4. Time in type	Number of hours pilot has in type plane, e.g., 1 to 50, 51 to 100, etc.
5. Purpose of flight	
BC	Business - Commercial
BI	Business - Individual

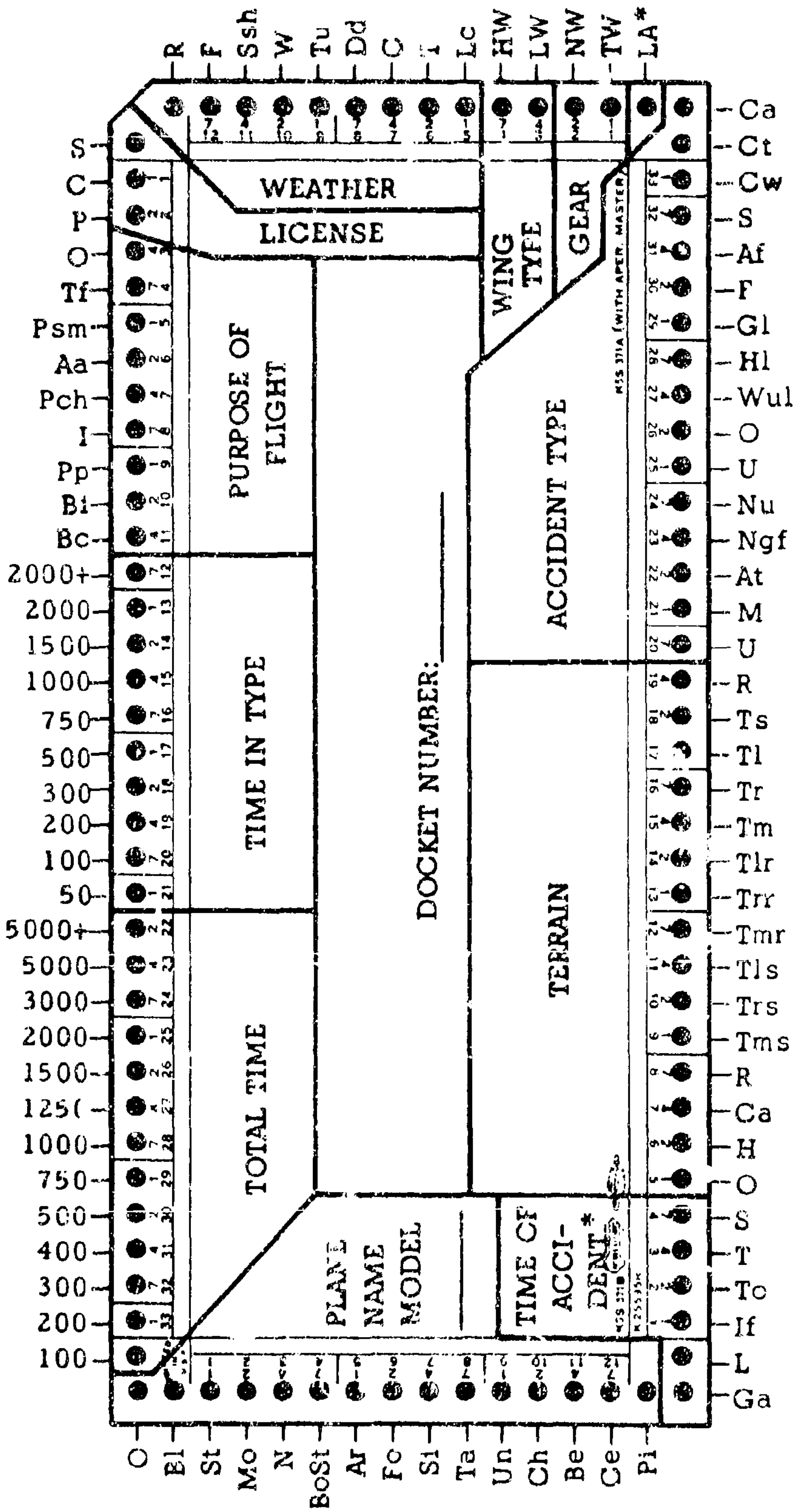

FIGURE 3. MASTER CARD

PP	Pleasure or personal
I	Instruction, dual or solo
PCH	Passenger and cargo transportation for hire
AA	Aerial application
PSM	Patrol, survey and misc. work
TF	Test, ferry, etc.
O	Other (stolen planes, etc.)

6. License — Private, student or commercial

7. Weather (only if a factor in the accident)

R	Rain
F	Fog
SSH	Snow, sleet, hail
W	Wind, cross, gusty, etc.
TU	Turbulence
DD	Down draft
C	Clouds
T	Thunderstorm
LC	Low ceiling

8. Configuration

HW	High wing
LW	Low wing
NW	Nose wheel gear
TW	Tail wheel gear

9. Accident type

CA	Collision with airplane
CT	Collision with terrain
CW	Collision with wires, trees, ruts, etc.
S	Spin or stall
AF	Airplane failure, all accidents resulting from structural failure of the airplane or control system.
F	Fire
GL	Ground loop
HL	Hard landing - resulting in damage
WUL	Wheels up landing, forgot to extend gear

O	Overshot landing area
U	Undershot landing area
NU	Nose up or nose over
NGF	Nose gear failure, not mechanical
AT	Aborted take-off improperly
M	Other miscellaneous accidents
U	Undetermined because plane is missing

10. Terrain (where applicable during landing or take-off)

R	Runway-prepared, dry, officially sanctioned strip
TS	Taxi strip
TL	Terrain, level
TR	Terrain, rolling
TM	Terrain, mountainous
TLR	Terrain level, rough or rocky
TRR	Terrain, rolling, rough or rocky
TMR	Terrain, mountainous, rough or rocky
TLS	Terrain level, soft, snow, soggy
TRS	Terrain, rolling soft, snow, soggy
TMS	Terrain, mountainous, soft, snow
R or B	River bed or beach
CA	Confined area
H	Highway or road
O	Other

11. Time of accident

S	Static
T	Taxiing
TO	Take off
IF	In flight
L	Landing
LA	Landing approach
GA	Go around

RESULTS OF CONTROL STUDY

Experience

3.10 A highly significant result of the study concerns pilot experience in type. This refers to the number of hours a pilot has logged in a certain model. Pilots with under 100 hours in type were involved in 60% of the 1660 accidents in the sample. Total experience of the pilot had less bearing on the likelihood of an accident. The following summary indicates the frequency of accidents for various experience groups:

Time in Type (Hours)	% of Total Accidents (N = 1660)	Total Time (Hours)	% of Total Accidents (N = 1660)
1-100	60	1-100	24
101-400	20	101-400	26
401-2000	14	401-2000	29
2000 +	2	2000 +	19
Unknown	4	Unknown	2
Total	100	Total	100

3.11 The table above shows the predominance of accidents occurring to the low experience in type group. A further examination of this group reveals that pilots with under 50 hours in type had 47% of the 1660 accidents in the sample.[8/] The under 50 hours in type group was composed of 788 pilots with varied total experience:

Under 100 total hours: 43%
101-400 total hours: 26%
Over 401 total hours: 31%

3.12 No statistics are presented with regard to the various proportions of the total civilian flying time accrued by pilots with less than 50 hours experience, 50-100 hours experience, etc. Exposure statistics of this nature are not presently available in civilian aviation data. Records kept by the Army do include this information, and consequently studies of Army accident rates could be made on the basis of exposure, leading to more conclusive results concerning the influences of total flying time and time in type on the accident rates, for all types of accidents.

8/ Appendix B: Table 1.

License

3.13 The license types were distributed among the 1660 pilots of the sample as follows:

Student	23%
Commercial	33%
Private	44%

Examination of the accidents occurring during the difficult landing phase reveals that the student pilots had 64% of their accidents during the landing phase, that the private pilots had 59%, and that the commercial pilots had only 44%.

Purpose of Flight

3.14 All accidents were classified under categories of Pleasure, Business, or Instruction. Business included: Business transportation not for hire, passenger and cargo transportation for hire, patrol, survey miscellaneous work, test, ferry, etc. Instruction included: student pilot, commercial pilot engaged in instructing. The following summary shows the percentage of accidents by purpose of flight:

Purpose of Flight	No. of Accidents	Per Cent
Business	654	39
Pleasure	558	34
Instruction	448	27

In 1957 the Federal Aviation Agency reported the following distribution of flying time:

Business	65%
Pleasure and personal	19%
Instruction	17%

The Business group which flew at least 65% of the total number of hours had only 39% of the accidents in the sample.

3.15 The results of the study indicate that current experience in type is the most important factor in accident prevention. The cost of additional hours of flying time in a given type while under competent instruction could be evaluated in terms of the expected lowering of the accident rate. The maintenance and fuel costs per flight hour for Army airplanes are shown in Figure 4.

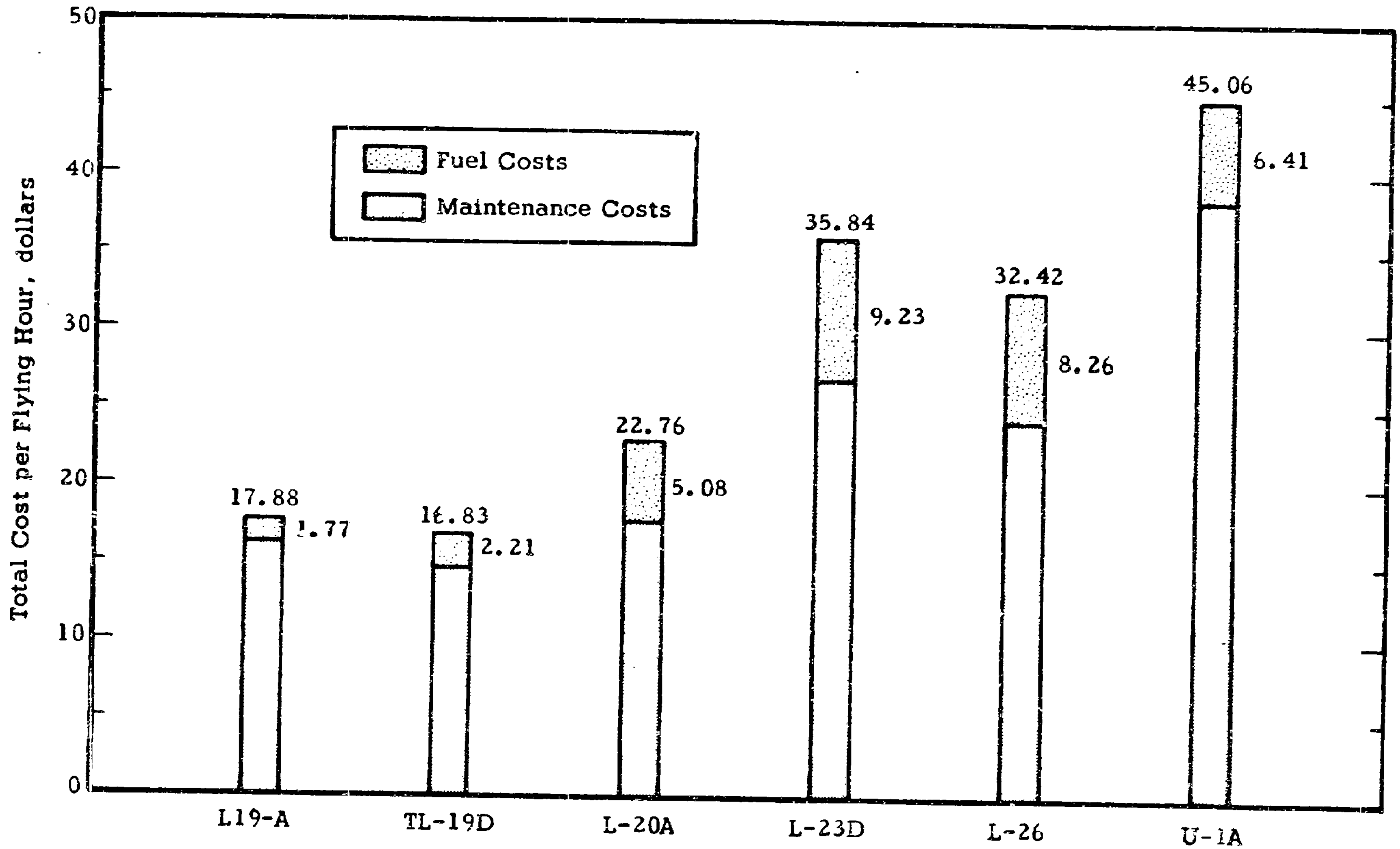

FIGURE 4. 1959 TOTAL MAINTENANCE AND FUEL COSTS PER FLYING HOUR FIXED WING AIRCRAFT

(Data taken from Maintenance and Operating Costs of Army Aircraft-III, U.S. Army Transportation Material Command, St. Louis, Missouri, February 1960)

3.16 It was expedient to use time intervals of increasing size in analyzing the accidents by the card system. To present the results meaningfully on graphs it was necessary to reduce the data to equal time intervals. Intervals of 50 hours were chosen to demonstrate the importance of added experience. This was done by plotting a cumulative total of accidents against the irregular time intervals as illustrated in Figure 5. The percentages for 50 hour intervals were charted anew as percentage of accidents versus experience at uniform 50 hour intervals. The distribution of total accidents versus time in type and total time is shown in Figure 6.

Phase of Operation

3.17 Phase of operation indicates the specific period in which the accident occurred. The most hazardous phase of operation is landing. The following summary indicates the frequency of accidents in the sample during the eight phases of operation:

Phase of Operation	No. of Accidents	% of Total Accidents in 1960 (N=1660)	% of Accidents in 1958 1/
Landing	898	54	52
In flight	306	18	18
Take off	206	12	19
Taxiing	110	7	9
Landing approach 2/	85	5	
Go around 3/	35	2	
Static	13	1	2
Undetermined (missing)	7	1	100
Total	1660	100	

1/ General Aviation Accidents (Non-Air Carrier). A Statistical Analysis Calendar Year 1958, Federal Aviation Agency, Washington, D.C.

2/ Included in Landing Accidents in the 1958 Report of the Federal Aviation Agency.

3/ Included in Take off Accidents in the 1958 Report of the Federal Aviation Agency.

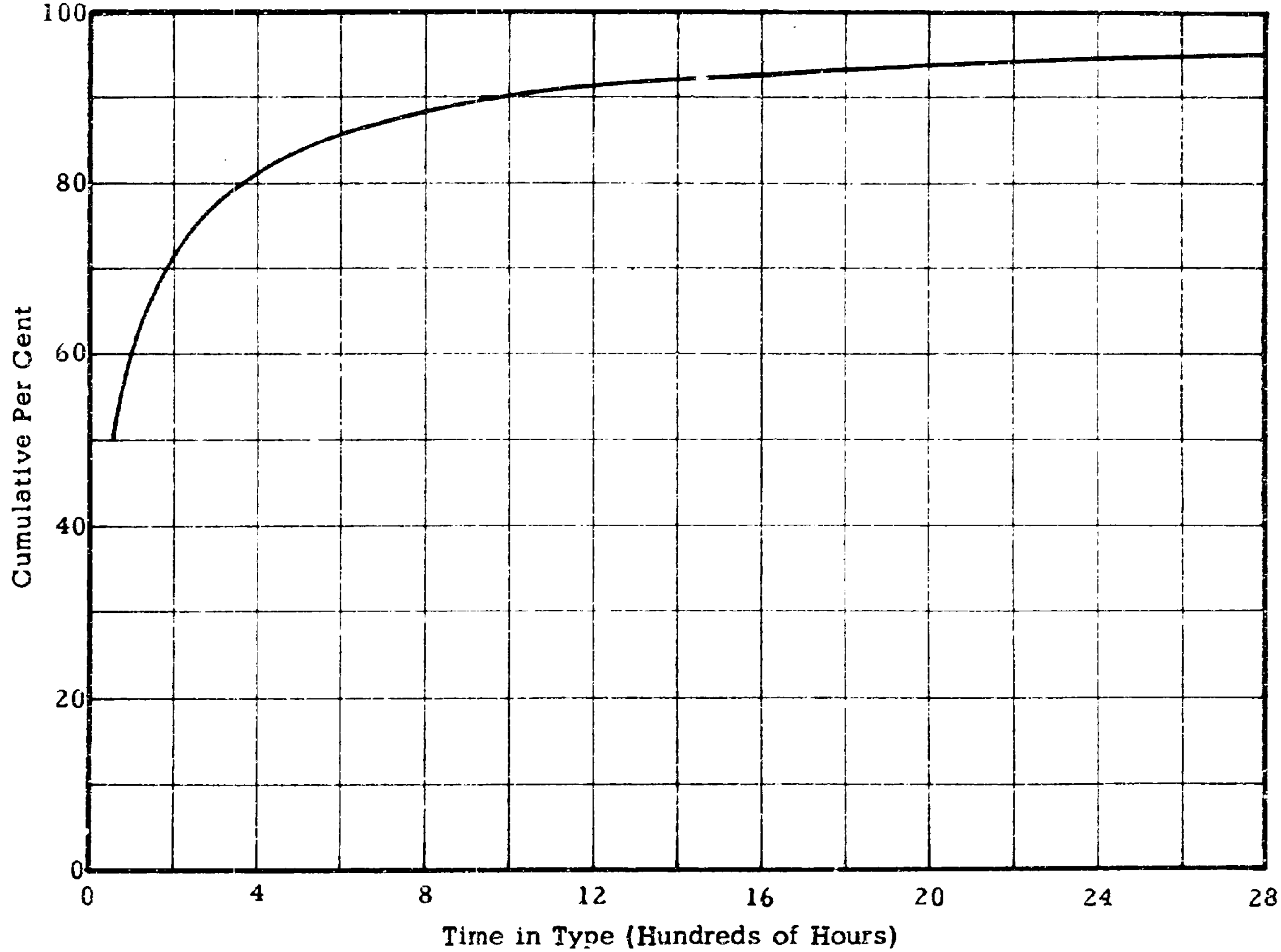

FIGURE 5. CUMULATIVE PERCENTAGE OF TOTAL ACCIDENTS

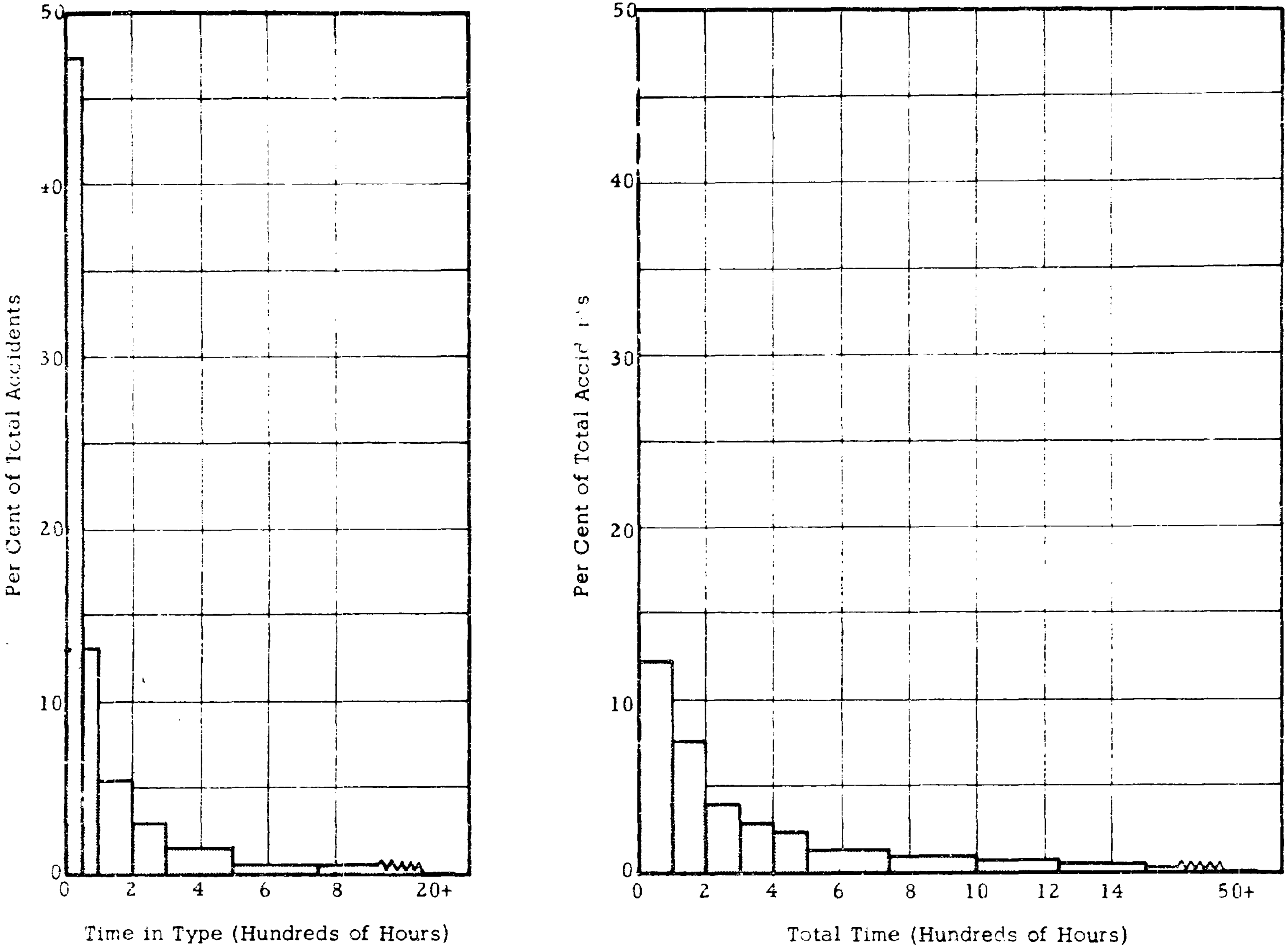

FIGURE 6. DISTRIBUTION OF 1660 ACCIDENTS IN STUDY

3.18 Landing Accidents. Landing accidents include all accidents that happen during the period from the time the landing gear touches the ground to the end of the landing roll on the runway, or to the time when the aircraft slows to taxiing speed. Landing accidents accounted for 54% of the 1660 accidents in the sample. The following table shows the kinds of landing accidents and their frequency:

Accident	Number	Per Cent
Nose-up, nose-over	146	16
Airplane failure	117	13
Ground loop	106	12
Collision, objects	102	11
Wheels-up landing	94	10
Nose-gear failure	83	9
Hard landing	82	9
Overshoot	70	8
Undershoot	44	5
Other Miscellaneous	54	6
Total	898	100

Pilots with under 50 hours in type accounted for 51% of the landing accidents. The distribution of landing accidents versus time in type and total time is shown in Figure 7.

3.19 In-Flight Accidents. In-flight accidents include all accidents that happen during the period starting from the completion of the climb-out phase, when the aircraft has reached the desired altitude for flight, until the time when landing procedures are begun and the landing checkoff list is employed. In-flight accidents accounted for 18% of the 1660 accidents in the sample. The following table shows the kinds of accidents occurring in flight and their frequency:

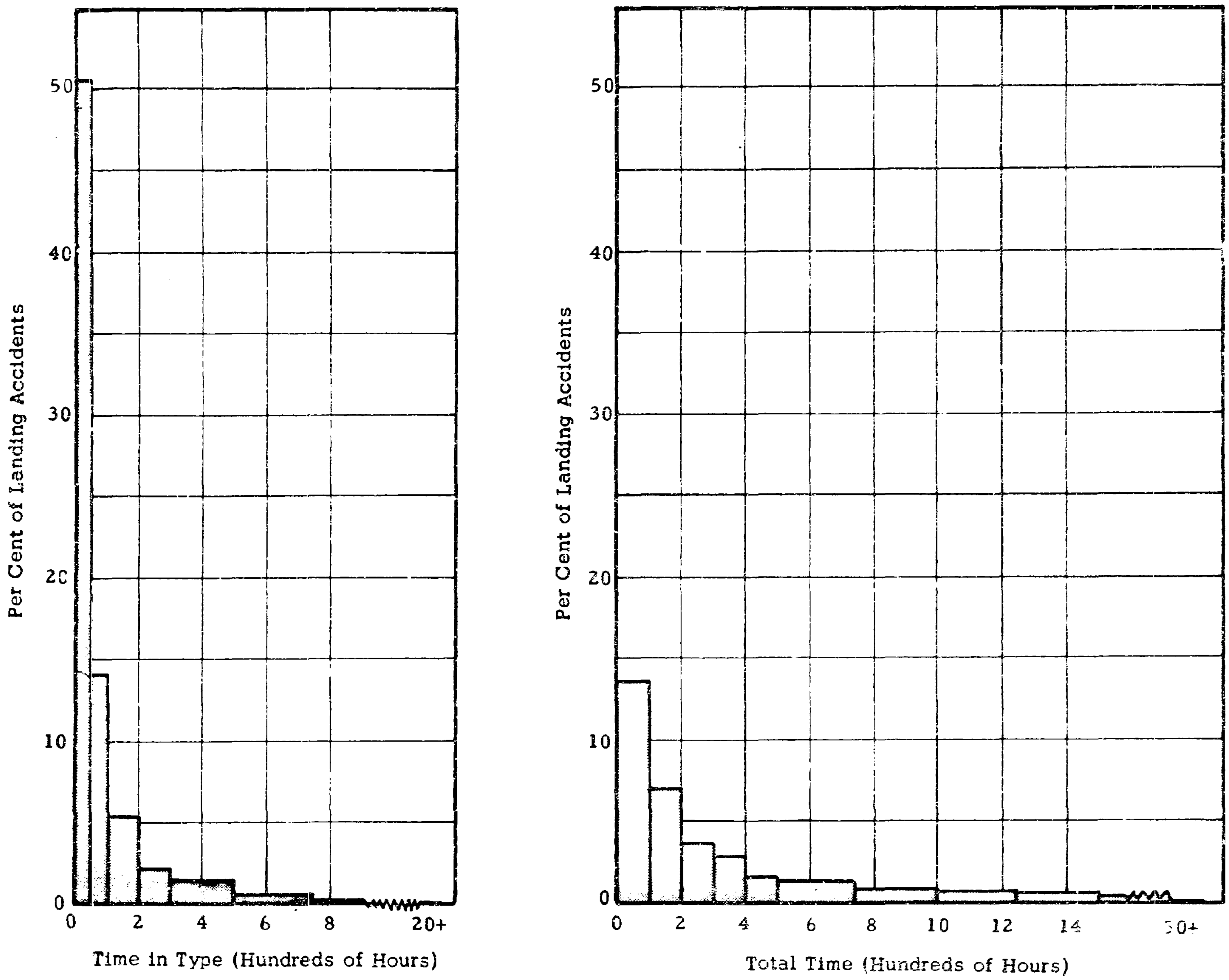

FIGURE 7. DISTRIBUTION OF LANDING ACCIDENTS

Accident	Number	Per Cent
Collision-terrain	88	29
Stall and crash	77	25
Collision-objects	71	23
Airplane failure	49	16
Undetermined (missing)	10	3
Collision-airplane	5	2
Fire	4	1
Miscellaneous	2	1
Total	306	100

Experience in type was a less important factor in this category. Pilots with under 50 hours in type accounted for 36% of the in-flight accidents. The distribution of in-flight accidents versus time in type and total time is shown in Figure 8.

3.20 Accidents During Takeoff. This includes all accidents that happen from the time of application of power for takeoff run, during climb and climb out to the altitude where the in-flight phase begins. Takeoff accidents account for 12% of the 1660 accidents in the sample. The following table shows the kinds of accidents during takeoff and their frequency.

Accident	Number	Per Cent
Collision-objects	50	24
Nose-up, nose over	34	16
Spin, stall	33	16
Aborted takeoff	29	15
Ground loop	17	8
Airplane failure	16	8
Collision-terrain	15	7
Other accidents	12	6
Total	206	100

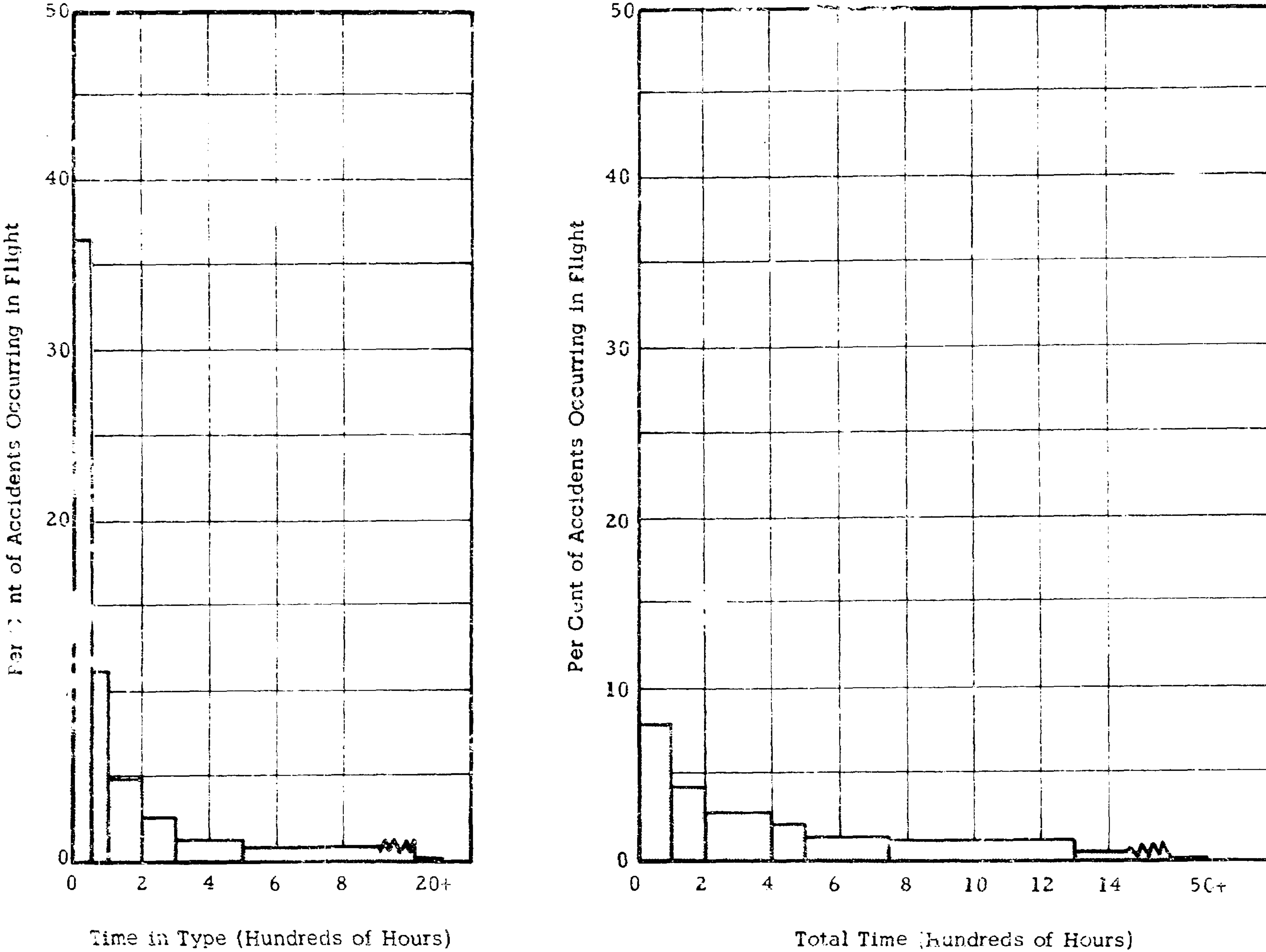

FIGURE 8. DISTRIBUTION OF ACCIDENTS OCCURRING IN FLIGHT

Pilots with under 50 hours in type accounted for 51% of the accidents during takeoff. The distribution of accidents during takeoff versus time in type and total time is shown in Figure 9.

3.21 Taxiing Accidents. Taxiing accidents include all accidents during the period when the aircraft is in motion on the ground, under power prior to application of throttle for takeoff, and subsequent to completion of the landing roll. Taxiing accidents accounted for 7% of the 1660 accidents in the sample. The following table shows the kinds of accidents that occurred during taxiing and their frequency:

Accidents	Number	Per Cent
Collision-objects	36	33
Nose-up, nose-over	36	33
Nose gear failure	13	12
Collision-airplane	8	7
Airplane failure	6	5
Other accidents	11	10
Total	110	100

Pilots with under 50 hours in type accounted for 45% of the taxiing accidents. The distribution of accidents during taxiing versus time in type and total time is shown in Figure 10.

3.22 Other Phases of Operation This category includes all accidents which happen during:

a. Landing Approach - that period from the time the pilot begins landing procedures and employs the landing checkoff list until the landing gear first touches the ground. This phase accounted for 5% of the 1660 accidents in the sample.

b. Go Around - begins at the time when the pilot aborts his landing attempt on final approach and attempts to regain sufficient airspeed and altitude to go around. This phase accounted for 2% of the 1660 accidents in the sample.

FIGURE 8. DISTRIBUTION OF ACCIDENTS OCCURRING IN FLIGHT

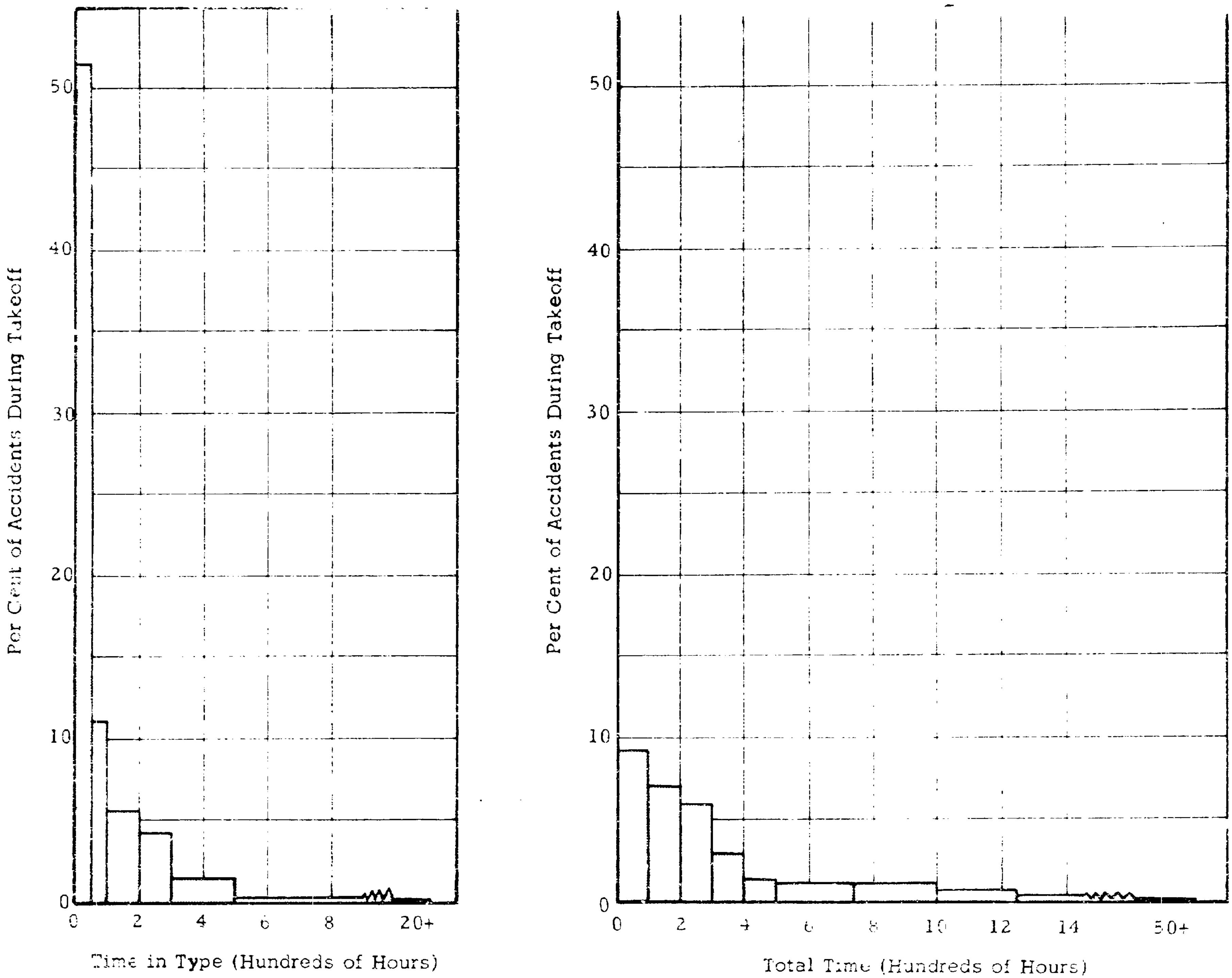

FIGURE 9. DISTRIBUTION OF ACCIDENTS DURING TAKEOFF

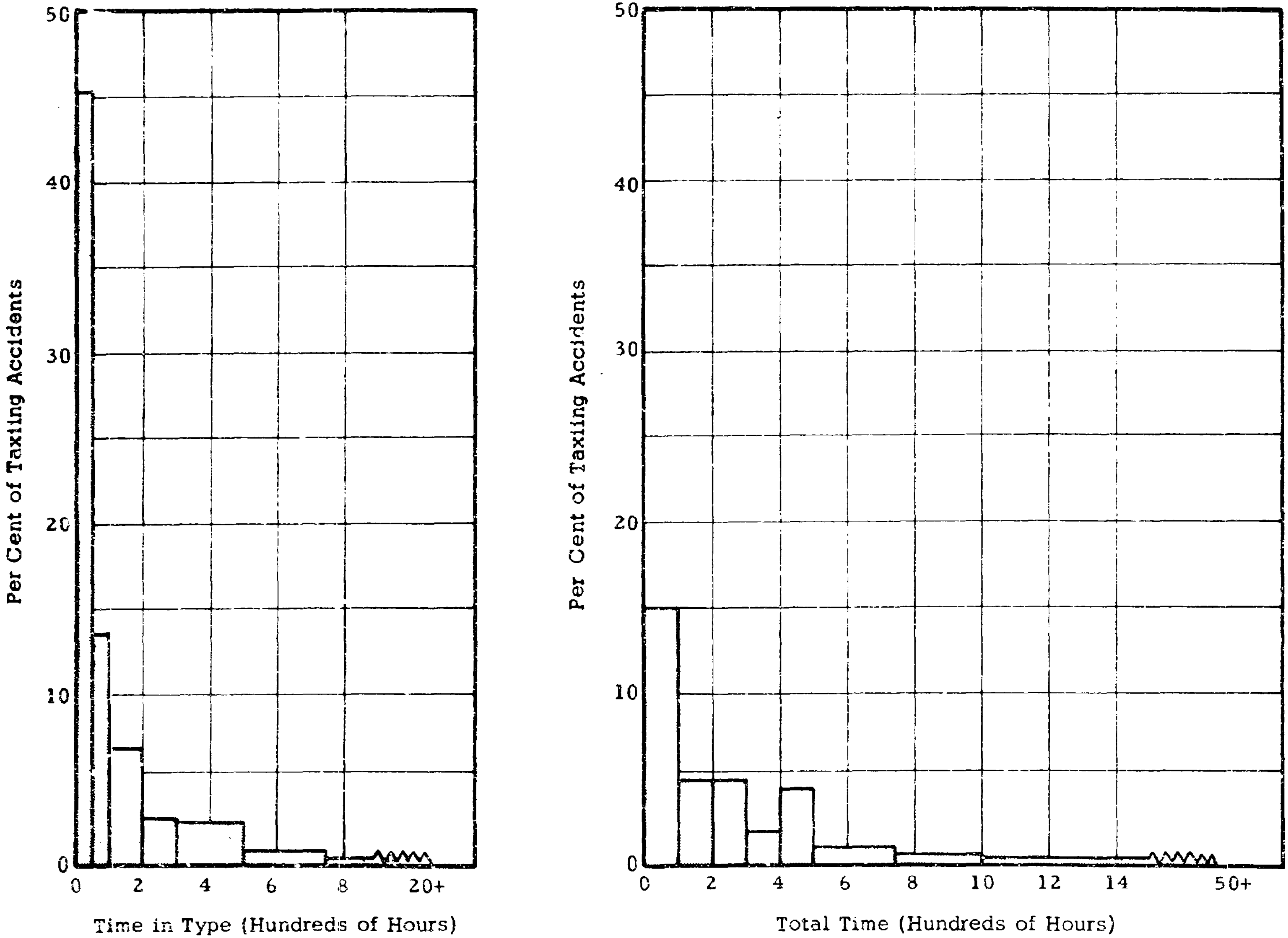

FIGURE 10. DISTRIBUTION OF TAXIING ACCIDENTS

c. Static - those periods during which the airplane is started, warming up for flight, or shutting down after flight. This phase accounted for 1% of the 1660 accidents in the sample.

d. Undetermined - when the plane was missing and adequate information had not been obtained. This accounted for less than 1% of the accidents in the sample.

Configuration

3.23 The majority (53%) of the planes registered with the Federal Aviation Agency on 1 January 1960 were high-wing, tail-wheel gear planes. Since most of the Army fixed-wing planes are high-wing, tail-wheel gear planes, an accident study of this particular configuration is warranted. Study of other configurations is also necessary to determine specific data regarding the accident rates for low-wing, nose-wheel gear planes; for high-wing, nose-wheel gear planes; for low-wing, tail-wheel gear planes.

3.24 The following summary shows the number of planes per accident for various configurations:

Landing Gear	Wing Placement	Active Planes as of 1-1-60	Number of Accidents in Sample	Planes per Accident
Nose-wheel	Low	12,800	342	37
	High	12,686	355	36
Tail-wheel	Low	2,061	94	22
	High	33,660	770	44
	Bi-wing	2,550	99	25

3.25 A survey of the accidents occurring during selected phases of flight is indicated in the following table:

	Wing Placement	Active Planes as of 1-1-60	Planes per Accident			
			Landing	In-flight	Takeoff	Taxiing
Nose-wheel	Low	12,800	59	256	346	853
	High	12,686	65	295	373	244
Tail-wheel	Low	2,061	39	103	159	412
	High	33,600	81	263	309	886
	Bi-wing	2,500	119	38	192	—

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IV. INFLUENCE OF LANDING GEAR CONFIGURATION ON LIGHT PLANE ACCIDENTS

4.1 When considering the design of future Army light planes, the question arises as to the most advantageous landing gear for this class of airplane. To provide a partial answer to this question, a study was made to evaluate the influence of landing gear configuration on light-plane landing accidents. The data for this study was drawn from the 1660 CAB Accident Reports of Section III. Of the 1660 accidents, 367 were classified as accidents due to landing gear configuration.

4.2 The CAB Accident Reports detail accidents which happen in all kinds of weather, in all seasons of the year, to a variety of pilots, commercial, private, and students. The flights were made for business, pleasure, or instruction purposes. A total of 62 different light-plane models were involved in the landing accidents selected. It is believed that the Accident Reports represented an excellent cross section of airplane accident data from which to draw a suitable example of landing accidents.

4.3 Purpose. The purpose of this study is to evaluate the influence of landing gear configuration on light-plane landing accidents. Two gear configurations are considered:

a. Tailwheel gear.

b. Nosewheel gear.

4.4 General Considerations. The tailwheel-type landing gear consists of two main wheels placed slightly ahead of the airplane center of gravity, and a tail wheel at the rear of the fuselage. In the nose wheel

type landing gear design, the two main wheels are positioned slightly behind the center of gravity, and a nose wheel is placed far forward on the fuselage.

4.5 The stated advantages of the tail wheel arrangement are as follows:[1,2]

a. The tail wheel is minimum weight compared to a nose wheel for an equivalent airframe, because the tail wheel is disposed at the rear of the airplane.

b. The tail wheel is located in a part of the fuselage not needed for equipment or for storage.

c. When landing, some of the airplane's total forward energy is dissipated due to the tail-down attitude, energy which would otherwise have to be absorbed by the brakes.

d. The location of the main, braked wheels in front of the center of gravity means that the wheel loading is increased when the brakes are applied.

4.6 Disadvantages of the tailwheel arrangement are:

a. Heavy braking can cause the airplane to nose-over, and the degree of braking must be restricted to safe values.

b. Brake drag forces, being applied forward of the center of gravity, cause a tendency for the airplane to swing around. Considerable pilot skill is required when brakes are heavily applied; the swing-around factor is perhaps the main criticism of the tailwheel arrangement.

c. On touch-down the tail drops, causing a tendency for aerodynamic bouncing or "ballooning".

1/ H.G. Conway, Landing Gear Design, (Chapman and Hall Ltd., London: 1958), pp. 6-8.

2/ F.K. Teichman, Airplane Design Manual, 4th Ed. (Pitman Publishing Company, New York: 1958), pp. 357-370.

d. The pilot's visibility during taxiing is poor.

e. Takeoff is hindered by the increased drag until the tail can be raised.

f. The loading of the airplane with freight and passengers is complicated by the inclined floor line.

4.7 The stated advantages of the nosewheel arrangement are as follows:

a. Heavy braking is not likely to cause nosing over.

b. The airplane when landing, particularly in a crosswind, is inherently stable, as the center of gravity is ahead of the main wheels.

c. At touch-down the airplane pitches forward, spoiling the wing lift and eliminating the risk of aerodynamic bounce.

d. The pilot's visibility is good at all times.

e. There is no loss of take-off performance due to drag from a tail-down attitude during initial acceleration.

f. The short wheel base facilitates maneuvering.

g The floor line of the airplane is essentially horizontal.

4.8 Disadvantages of the nosewheel arrangement are:

a. A nose wheel will be heavier than a tail wheel for an equivalent airframe, due to the short wheel base, and also due to the forward pitching of the airplane during braking which increases the dynamic loads on the nose wheel.

b. The nose wheel causes more difficulty in retraction because of its location in the forward portion of the fuselage and because of the long shock-absorber travel.

c. Very little of the airplane's forward energy is dissipated by air drag during landing.

- d. Heavy braking causes a reduction of main wheel loading, tending to cause main wheel skidding.

- e. Difficulty may be encountered with the nose wheel in riding over obstacles. The tail wheel seems to behave better under the same circumstances.

- f. The rear portion of the fuselage may be damaged in case of an unusual "tail-low" landing.

4.9 New light planes are generally being equipped with nosewheel gear. Several factors may influence this design being favored over the older tailwheel arrangement. The nosewheel gear gives greater ground stability since the three wheels are likely to be evenly loaded at all times. There should be little tendency to nose-over since the nose wheel, being ahead of the center of gravity of the airplane, resists nosing over. Thus, there is the possibility of landing at almost any angle of attack. For the tyro pilot, this is a very good feature, since the landing technique need not be letter perfect

4.10 Statistical Analysis of Light Plane Landing Accidents. The Civil Aeronautics Board Accident Reports, General Aviation, were carefully studied to determine the effect of landing-gear configuration on light-plane landing accidents. These accidents were analyzed and reported on by the CAB during the period 1 March 1960 through 31 July 1960. In performing an analysis, certain light-plane landing accident criteria were developed by which the various Accident Reports were classified.

Landing Accidents

4.11 Landing accidents are those accidents which occur during or after the first touchdown for landing. Examples are:

- a. Plane bounces down hard and damages the structure.
- b. Plane runs off runway.
- c. Plane hits fence.
- d. Plane ground loops.

This category does not include accidents which occur prior to first touch-down i.e., plane hits telephone wire while descending, stalls out five feet over the ground, or pilot loses control and plane spirals onto the ground.

Landing Accidents Due to Gear

4.12 Landing accidents due to gear are those accidents which are influenced by the landing-gear configuration. Examples are:

a. Ground loop.

b. Nose-over

c. Nose-up.

d. Nosewheel collapse.

This category does not include those landing accidents not influenced by the landing gear configuration, i.e., pilot fails to extend gear, plane overshoots runway, brake failure.

Description of Landing Accidents

4.13 The following descriptions of landing accidents are those adopted for use in the study.

a. Ground Loop. A sharp uncontrollable turn on the ground during landing, due to wind gust or improper braking by pilot.

b. Nose Gear Collapse. Plane hits slight obstruction, rock, hole, rut, etc., and nose wheel breaks off, is bent back, or tire blows out, with subsequent damage to plane.

c. Nose-over. Plane tips up on nose and then flips tail over nose and comes to rest inverted.

d. Nose-up. Plane tips up on nose and settles back on landing gear.

4.14 The data obtained from the landing accident study, classified according to the criteria of paragraph 4.11, are presented in Figure 11.

4.15 To place the light-plane landing accident data on an absolute basis, the total number of civilian light planes of interest, classified as to type of landing gear, was determined.[3/] The numbers obtained were combined with the accident data of Figure 11 to compute the

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[3/] Federal Aviation Agency, Statistical Study of U.S. Civil Aircraft as of January 1960.

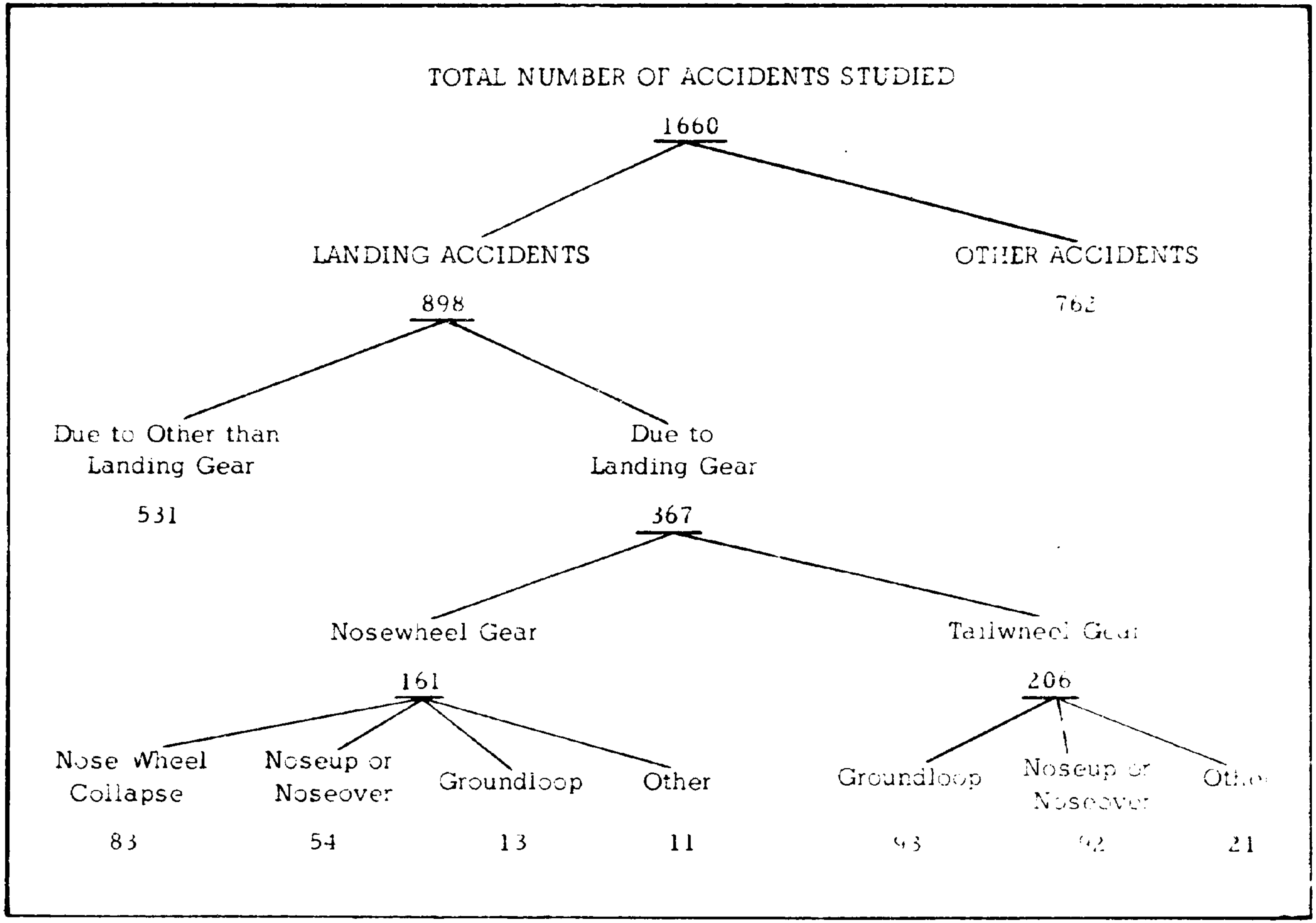


FIGURE 11. STUDY OF CIVIL AERONAUTICS BOARD ACCIDENT REPORTS

landing accident frequencies shown in Figure 12. Figures were not available to determine the exposure for each type of airplane, i.e., hours flown, number of landings. Therefore, it was necessary to make the assumption that the number of flights made by a given airplane type is independent of that airplane type.

4.16 Results. The results of the statistical analysis indicate that the frequency of landing accidents due to gear configuration is somewhat less for tailwheel planes than for nosewheel planes:

Tailwheel Gear —

$$\frac{\text{206 (number of accidents due to gear, out of 1660 accidents studied)}}{\text{38,271 (total number of active light planes with tailwheel gear)}}$$

$$= 0.0054 \qquad \text{(186 planes/accident).}$$

Nosewheel Gear —

$$\frac{\text{161 (number of accidents due to gear, out of 1660 accidents studied)}}{\text{25,486 (total number of active light planes with nosewheel gear)}}$$

$$= 0.0063 \qquad \text{(158 planes/accident).}$$

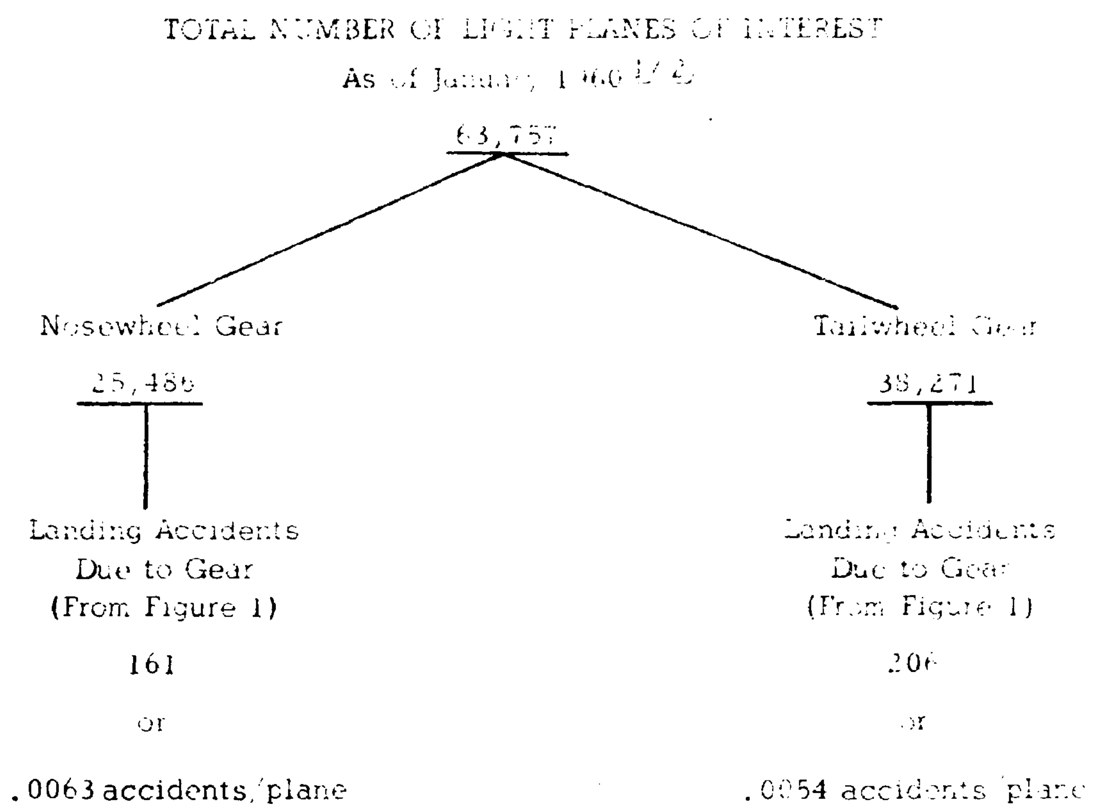
4.17 The types of landing accidents due to landing gear are shown in Figure 13, along with percentage occurrence in the sample taken. It will be seen that nosewheel collapse accounted for the great majority of nosewheel gear accidents. Groundloops and nose-over share almost equal responsibility for tailwheel gear accidents.

4.18 Three landing conditions are encountered:

a. Rough — any area which is not a prepared, dry landing strip. Includes wet strips, snow covered areas, plowed fields, sand, etc.

b. O.K. — any prepared, dry landing strip.

c. Wind — crosswind, gusts, wind storms, all prevailing over prepared strip.



1/ Federal Aviation Agency, Statistical Study of U. S. Civil Aircraft (1960).

2/ Federal Aviation Agency, Aircraft Specifications.

FIGURE 12. LANDING ACCIDENT FREQUENCY

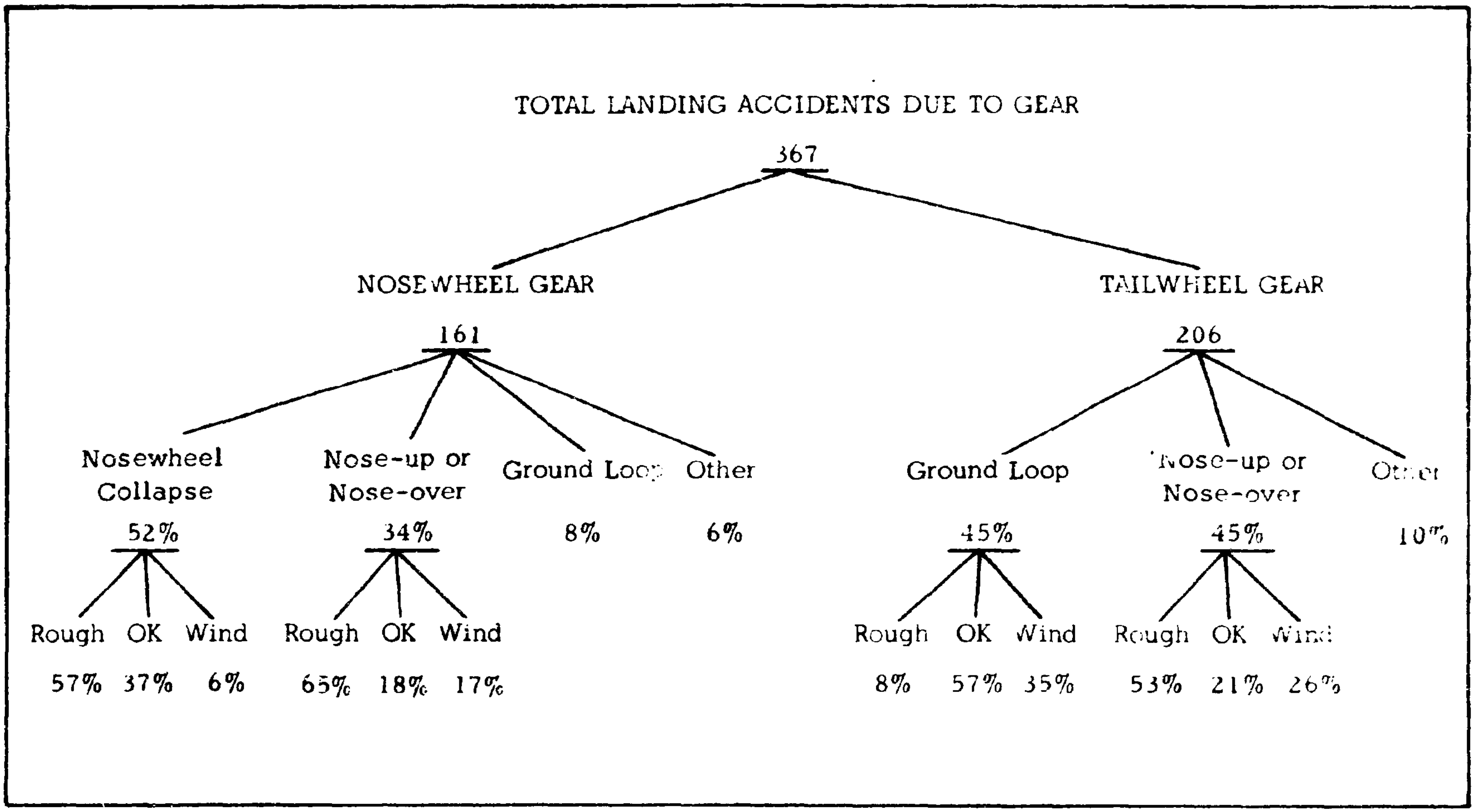


FIGURE 13. RELATIVE OCCURRENCE OF VARIOUS LANDING ACCIDENTS

TABLE 1

LANDING CONDITIONS ENCOUNTERED IN 472 ACCIDENTS

Landing Condition	Number	Percentage
Rough	152	41%
O.K.	143	39%
Wind	72	20%

In Figure 13, the major types of landing accidents due to gear are detailed with regard to the three landing conditions. These percentages indicate the following:

1. Nosewheel Gear

   a. Nosewheel collapse occurs predominantly in rough fields.

   b. Nose-over commonly occurs in rough fields.

2. Tailwheel Gear

   a. The majority of ground loops occur under "O.K" conditions.

   b. Nose-over occurs predominantly in rough fields.

4.19 Table 2 lists the frequencies of landing accidents due to gear for certain of the light planes of the study. These figures are of interest because some of the planes built by a given manufacturer are generally similar except for the gear arrangement employed. In particular, the "A" line consists of almost identical airplanes, some being nosewheel equipped, others tailwheel equipped.

4.20 A previous study[4] made by ORI to evaluate the influence of landing gear configuration on light-plane landing accidents used data drawn from an older set of CAB accident reports. These accidents, 2310 in number were analyzed and reported by the CAB during the period

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[4] Alan D. Morris and Joann Langston, Influence of Landing Gear Configuration on Light Plane Landing Accidents, ORI Technical Memorandum 112-60, 6 June 1960.

TABLE 2

LANDING ACCIDENTS DUE TO GEAR FOR CERTAIN ACTIVE LIGHT PLANES OF STUDY

Manufacturer	Number of Nosewheel Planes	Frequency of Landing Accidents Due to Gear* Per Cent	Number of Tailwheel Planes	Frequency of Landing Accidents Due to Gear* Per Cent
A	297	6.1	5062	0.5
B	5213	0.2	222	0.5
C			498	0.4
D			1934	0.4
E	8002	0.5	9572	0.8
F	2283	0.5		
G	520	1.0		
H	1213	0.6	118	
I	7668	0.8	10046	0.4
J			2426	1.1
K			2325	0.3
L	76		3115	0.4
M	214	1.9	2903	0.3

$$\text{*Frequency of Landing Accidents Due to Gear} = \frac{\text{Number of "X" airplanes involved in landing accidents due to gear}}{\text{Total number of "X" airplanes active in year of study}}$$

1 January 1959 through 31 March 1960. For the previous study, the total number of civilian light planes of interest, classified as to type of landing gear, was determined from the 1959 edition of "Statistical Study of U.S. Civil Aircraft." The results of the previous study, which are almost identical to the results of this Section IV study, are shown in Appendix D.

V. AIRCRAFT DESIGN

5.1 Improvements can be made in the design and location of aircraft instruments and controls, which facilitate quicker and more accurate pilot response to the changing conditions of flight. Some design considerations having particular importance to the problems of Army aviation are discussed in this section. These design considerations are studied in relation to task element analysis.

STALL WARNING DEVICES AND OTHER SAFETY INSTRUMENTATION

5.2 The pilot's recognition-and-reaction time is especially critical in the case of the stall, which is one of the most common causes of fixed-wing, in-flight accidents.[1/] Unlike ground loops, stall accidents are not characterized by the inexperience of the pilots, for experienced pilots habitually fly closer to stall and are thus more vulnerable to unusual distractions, unexpected air turbulence, and other factors which contribute to stalls. Furthermore, research has shown that many pilots and instructors do not know at what speed the stall occurs in the gliding turn, steep turn, and certain other maneuvers, even in the airplane used most frequently by the subject.[2/]

[1/] See Appendix C, Table 3.

[2/] P.J. Rulon, A Study of the Accuracy of the Incipient Stall in Familiar and Unfamiliar Planes, CAA and Education Research Corporation, Cambridge, Mass., November, 1947.

5.3 Stall accidents are generally associated with flying operations and maneuvers that tax the limits of the airplanes' and the pilots' capabilities. Army combat aviation often requires maximum performance, involving operations with maximum loads, on short fields, on high-altitude fields, and under conditions distracting to the pilot, such as low-altitude maneuvers near trees and other obstacles while accomplishing assigned missions. Low altitude flying in itself is particularly hazardous because of the short time available to recover from stalls.

5.4 With regard to the stall hazard, Army combat aviation is closely similar to aerial application work, in which professional pilots take off with maximum loading, fly at 10-30 foot altitudes, and execute tight turns at the end of each swath. The most frequent type of accident in aerial application work is collision with wires, poles and other obstacles. The second most frequent type is the stall accident.[3/]

5.5 In this section various means of avoiding stall accidents are considered. Attention is concentrated on the instrumentation available to provide stall warnings and "speed control". Since the Army is already familiar with these instruments and uses them in some airplanes, discussion will be restricted to their possible use on the L-19 airplane, and their use as standard equipment in future,fixed-wing airplanes procured for Army use.

Grumman AG-CAT Instruments

5.6 The new Grumman AG-CAT is a biplane especially designed for aerial application work. In locating the instruments of this airplane, the designers gave attention to the pilot's need to concentrate on his line of flight. Consequently, the airspeed indicator and the engine tachometer were placed on the top of the fuselage, a few inches forward of the cockpit. These frequently consulted instruments are thus closer to the pilot's flying line of vision, and the time required to read them is reduced. With this arrangement the pilot is able to pay more attention to both his flight path and to the instruments which help avoid stalls.

[3/] CAB, Accidents in Aerial Application Activities, Calendar Year 1957 Washington, D.C., October 31, 1958.

Special Instruments

5.7 Instruments presently used on the Army Caribou and Otter airplanes are designed to warn the pilot of the near-stall conditions. These instruments can present the warning signal in the form of a horn, a light, or a shaking of the control column. Since the Army has studied these instruments in detail, they will not be described here. However, the instruments are not currently used on the L-19 airplane, although the FAA requires their use on all Cessna airplanes produced for private and commercial flying.

5.8 The principal disadvantages of the pre-stall warning indicator are as follows:

a. At low speeds and in turbulent air, the warning signal may be frequently activated although a dangerous stall condition does not exist. Experienced pilots consider this objectionable.

b. A pilot's habitual dependence upon the warning signal may prove disadvantageous if the instrument becomes inoperative.

Advantage of such an instrument in airplanes having relatively good, natural stall warning characteristics must be considered in the light of these disadvantages together with cost, weight, and maintenance.

5.9 However, the Speed Control Indicator (SCI) performs a much more useful function than the stall warning device. Such an indicator permits the selection of optimum speeds for various phases of flight and maneuvers. Since the SCI automatically takes into account the effects of airplane loading, altitude, acceleration, and power, it quickly and accurately provides indication of the optimum angle of attack. This automatic indication is useful in selecting the maximum rate of climb, correct gliding angle, and correct banking angle, especially under conditions of maximum load.[4/] The SCI also obviates to some extent the need for stall warning by indicating "SLOW" when a stall condition is approached. It has been suggested that the SCI has greater utility than the airspeed indicator.[5/]

4/ "Taking the If out of Lift", Flying Safety, USAF, April 1956.

5/ John R. Hoyt, "Speed Control Indicator", Flying, October, 1956.

5.10 It is concluded that whereas simple stall warning devices may not be worthwhile in the L-19 airplane, or as standard equipment for future Army airplanes, the SCI offers several advantages for Army pilots flying under the stresses of combat conditions.

TRICYCLE LANDING GEAR

5.11 Because of the popular opinion that nosewheel airplanes are safer for private and civilian flying than airplanes with conventional landing gear,[6/] statistical studies were made on the influence of landing gear configuration and light plane landing accidents (see Section IV). The results of these studies indicate that nosewheel airplanes have at least as many landing accidents as tailwheel airplanes, partly due to the greater vulnerability of the nosewheel structure on rough fields. Also, nosewheel airplanes characteristically require longer take-off and landing distances than tailwheel airplanes. Since Army combat missions will require the highest degree of reliability on unprepared, short fields, the conventional gear is therefore considered superior to the tricycle design for the Army's light airplanes.

OTHER SAFE LANDING DEVICES

5.12 A number of other devices to improve the landing capability of aircraft have been proposed by manufacturers. A few, such as periscopes for dead-ahead vision in tailwheel airplanes, and large, low-pressure tires for rough field landing,[7/] have potential advantages for high-performance aircraft. No special device has been found, however, which may be expected to improve the landing characteristics of light airplanes such as the L-19 without unwarranted sacrifices in space, weight, or cost.

[6/] Amony many interesting references on this subject is: Ralph C. George, "The 172 in the Bush", Flying, Vol. 64, July 1959, p. 34.

[7/] V. Frisby, "New Tire for STOL-Type Aircraft may Permit Rough Field Landings", SAE Journal, Vol. 65, Nov. 1957, p. 74. Also subsequent reports on high flotation landing gear by Fairchild Aircraft and Missile Division, Hagerstown, Maryland.

H-34A HELICOPTER INSTRUMENT PANEL

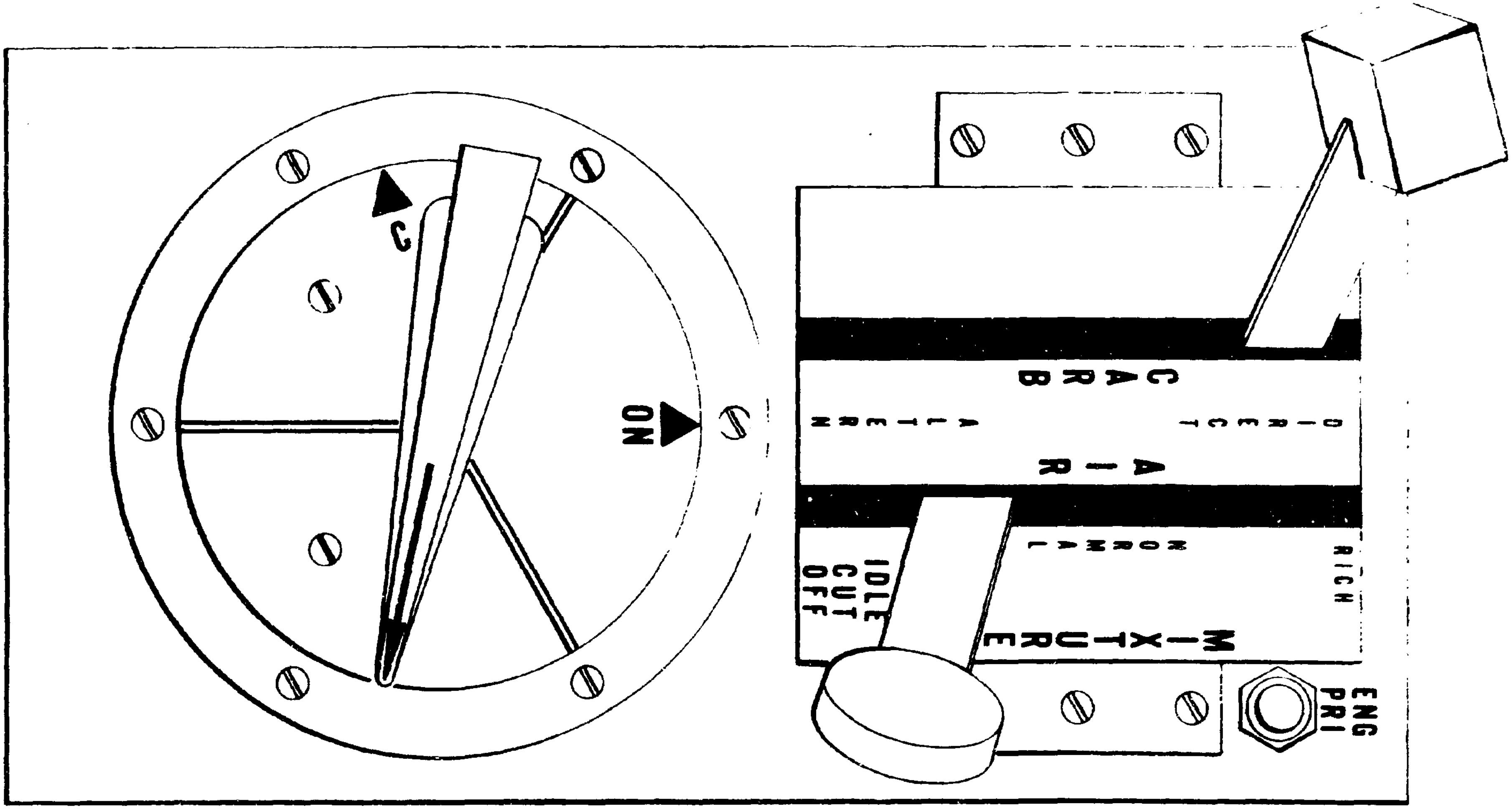
5.13 Figures 14, 15, and 16 are reproductions of three figures found in the USAF Series H-34A Helicopters Flight Manual. The figures are presented to illustrate human engineering flaws in the present instrument panel design. Conceivably, similar flaws can be prevented from appearing in future Army aircraft. None of the human engineering design flaws which follow appears particularly significant by itself. However, several human engineering flaws can be compounded by a fatigued pilot under difficult conditions into an accident situation.

1. Occluding of Position Settings. Both the fuel flow ~~selector~~ handle (Figure 14) and the ignition switch (Figure 15) illustrate the impossibility of knowing which position setting is indicated by these controls, without (1) moving the switches into other settings, or (2) projecting the difference between visible indications (those not occluded) and the total possible settings previously committed to memory.

2. Opposing Directional Movements Required for Placing Switches into the "ON" Position. Three of the two-position toggle switches on the main panel (Figure 15) must be moved downward to terminate their control functions. The OIL DIL switch, however, must be moved upward. All two-position switches on the same panel should be moved in the same direction for termination of functions. On vertically mounted panels, the preferred movement should be upward for ON, and downward for OFF.

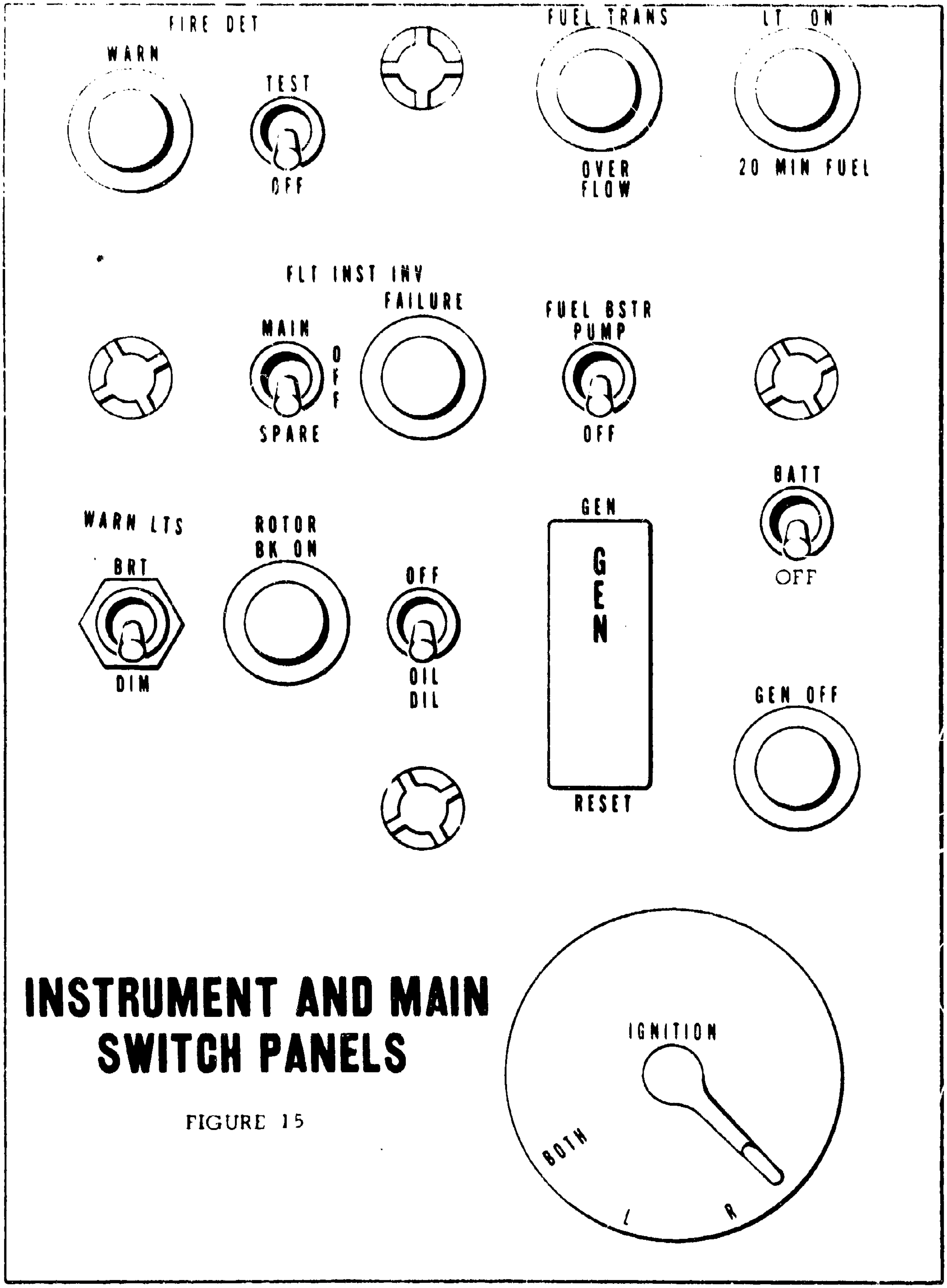
3. Misused Location Coding. Three-position toggle switches should be located in an area which is readily recognized as separate from the two-position toggle switch grouping (Figure 15). Relocation of three-position toggle switches is recommended because their "OFF" position is optimally located at the midpoint, and therefore would require either upward or downward movement to terminate a control function.

4. <u>Misuse of Identification Label.</u> The label which identifies a control is used, in addition to its descriptive function, both to indicate that a function is begun and and that a function is terminated. For example, in Figure 15, TEST, BATT, FUEL, BSTR PUMP, and OIL DIL mean that the respective functions are "ON". Conversely, in Figure 16, ROT LT, PILOT HEAT, CABIN PAN, and RADIO MASTER indicate that the function which these switches identify is turned OFF. Identification labels should be used solely to identify or describe the function which is controlled by the switch. The terms ON and OFF should be used to describe the state in which the identified function is operating.



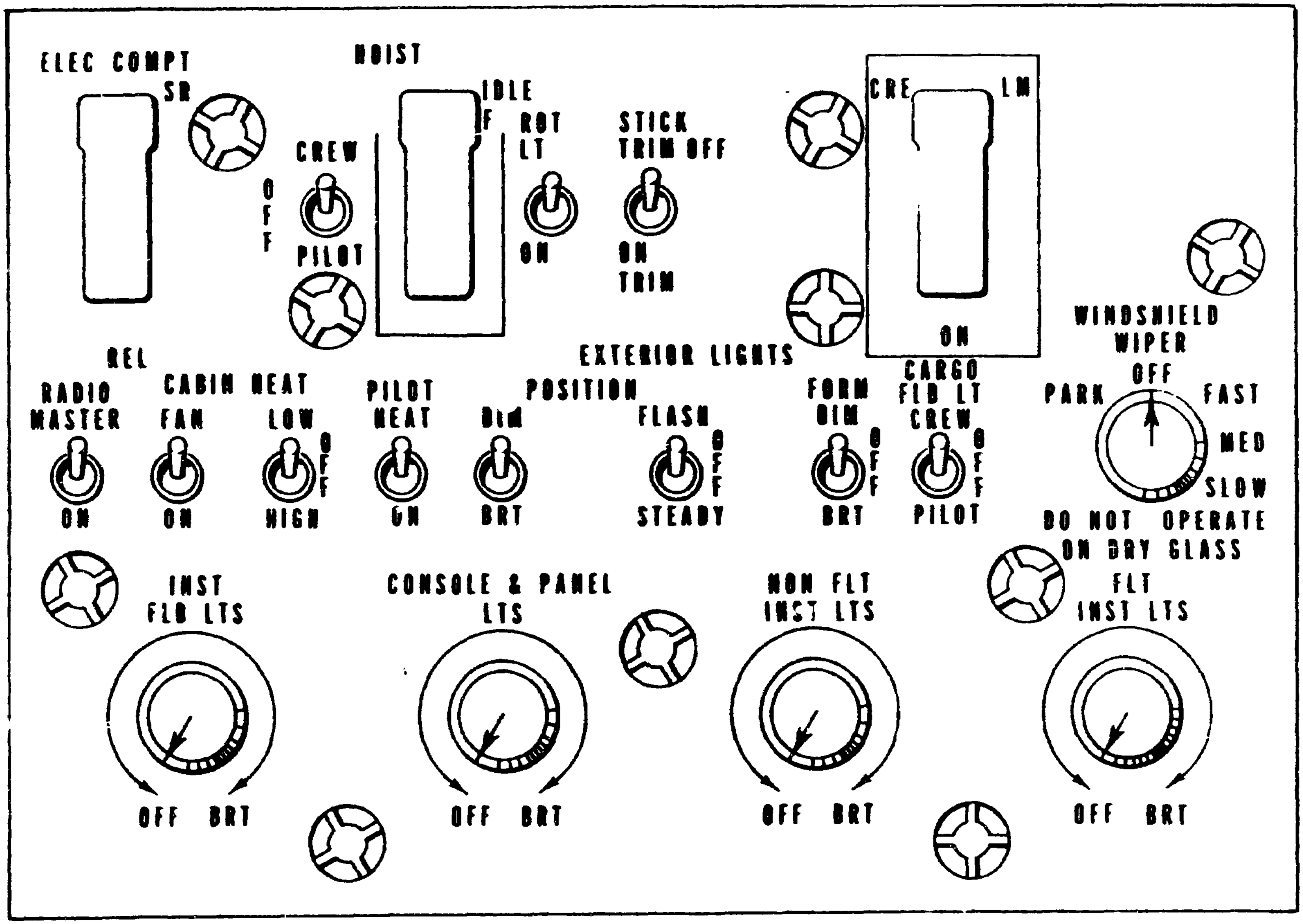
ENGINE QUADRANT, FUEL FLOW SELECTOR VALVE HANDLE

FIGURE 14



INSTRUMENT AND MAIN SWITCH PANELS

FIGURE 15



OVERHEAD SWITCH PANEL

FIGURE 16

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VI. RECOMMENDATIONS FOR FUTURE RESEARCH

Accident Analysis and Accident Prevention Studies

6.1 Studies of Army accident records should be performed to determine the influence of pilot experience on various types of accidents. The adequacy of training and proficiency flight time should be evaluated on an economic basis by relating accident costs to the costs of training and flight operations.

6.2 Complete lists of task elements should be developed for Army aircraft which are currently planned to be continued in use. The list of tasks during the more critical maneuvers and phases of flight should be developed in considerable detail by means of micromotion studies in instrumented test vehicles.

6.3 Task element data should be utilized to identify incompatibilities and indicate directions for increasing reliability of current flight operations. Such investigations would aid in:

a. Unburdening the pilot.

b. Speeding the pilot's response to emergency conditions.

c. Studying the feasibility of future Army aviation weapon systems.

6.4 A standard form for use in the investigation of aircraft accidents should be developed. The form should be designed to improve the consistency of accident investigation and analysis by emphasizing the needs for

comprehensive data collection and organization of data into a form aiding detailed analysis of the emergency and accident sequence. The form should encourage the application of task element data and the use of diagrams that include time and distance scales.

6.5 A pilot study should be designed and carried out involving the greatly detailed investigation of a limited number of airplane accidents involving situations pertinent to evaluation of human factors and design criteria.

6.6 Methods and standards should be developed for presentation of instructions and technical data in airplane operations manuals for Army fixed-wing airplanes and for helicopters.

Aircraft Design

6.7 Human factors check lists and design notes should be developed for specification and for mock-up evaluation of cockpit arrangement, visibility provisions, controls and instrumentation.

6.8 Studies and field tests should be continued for comprehensive evaluation of the speed control indicator with regard to possible future use on all fixed-wing airplanes.

6.9 Further studies for evaluation and possible standardization of tether-coupler assemblies for helicopter sling loading should be undertaken.

6.10 Further studies should be undertaken on landing gear configurations for increasing compatibility of new airplanes with army requirements for both mission and pilots with varying degrees of training.

Pilot Training

6.11 Studies should be undertaken to evaluate pilot proficiency at two or more selected durations of training and experience in type.

6.12 A study of instruction procedures should be undertaken for further development and standardization of optimal procedures for landing fixed-wing aircraft.

APPENDIX A

Presented as this appendix is the GENERAL CHECKLIST taken from the Handbook for Aircraft Accident Investigators, published by Headquarters, Department of the Army, August 1958 as PAM 95-5

GENERAL CHECKLIST

(Aircraft Type and Serial Number) (Date of Accident)

INSTRUCTIONS: This checklist is recommended for local reproduction, modified as required to fit local needs, for use of the aircraft accident investigator. A copy of it may be included in the investigator's final report if considered beneficial to any portion of that report. CHECK THE APPROPRIATE *YES* OR *NO* COLUMN—AFTER CHECKING THE *APPLICABLE* OR *INAPPLICABLE* COLUMN. Each item is a question.

Applicable	Inapplicable	Question	Yes	No
		I PRELIMINARIES		
		1. *a.* Was there a crash alarm system?		
		b. Did it function?		
		c Is it adequate?		
		d. Preaccident planning was wholly functional in use?		
		2. Guards posted and fully cognizant of their duties?		
		3. Rescue and fire procedures wholly functional for this specific accident?		
		4. Medical aid and evacuations rendered promptly and efficiently?		
		5. All personnel concerned fully aware of their individual responsibilities and joint purpose?		
		6. Official photographer arrived promptly and began photographic responsibilities without delay?		
		7. *a.* Newsmen handled efficiently and courteously?		
		b. Premature news releases avoided?		
		II. FIRST STEPS		
		8. *a.* Witnesses present on the scene?		
		b. All questioned fully (names, addresses, etc.)?		
		c. A check made with respect to missing witnesses?		
		9. Master sketch begun?		
		10. Search crew required?		
		11 Special assistance obviously necessary?		
		12. Any obvious signs of in-flight structural failure?		
		13. All diagnostic distances (between obstacles, pieces, etc) measured precisely and recorded on master sketch?		
		14. All occupants identified, evacuated promptly if injured and personal possessions preserved?		
		15. Was claims office notified of civilian property damage?		
		16. *a.* Any bailouts?		
		b. Identified?		
		c Located?		
		17. Investigative responsibilities clearly defined in the case of inter-service involvement?		
		18. Civil authorities (officials, agencies, etc.) notified where essential or advisable?		
		III INITIAL SPECIFICS		
		19. All aircraft parts, pieces, and equipment accounted for?		
		20. Any obvious oddities which must be explained?		
		21. Flight *altitude* prior to accident descent determined?		
		22. Flight *attitude* prior to first ground contact determined both longitudinally and laterally?		
		23. Lateral and longitudinal *attitude* at ground impact de-		

Applicable	Inapplicable	Question	Yes	No
		termined?		
		24. Any obstacle(s) hit before ground impact?		
		25. Speed at impact determined?		
		26. Angle of impact determined?		
		27. Type of ground (softness, elements, etc.) considered in relation to impact force(s)?		
		28. Secondary impacts, if any, determined in relation to force? Effects?		
		29. Angle from obstacle to initial ground impact determined?		
		30. Distance of travel and of structural displacement from initial impact accurately measured?		
		31. Gouge marks, if any precisely measured as to length, width, depth, shape, etc., as well as distance between one set of gouge marks and others?		
		32. Manner of travel (straight, cartwheeling, etc.) after impact taken into consideration and adequately vertified?		
		33. Any objects hit during post-impact travel?		
		34. Determined wind speed and direction at scene of crash, as related to flight path?		
		35. Determined effect of wind on aircraft speed? On debris pattern?		
		36. Added all necessary data to master sketch as determined, discovered, or measured?		
		37. Recorded all pertinent weather conditions? Possible significance of air turbulence and its cause? Relationship of such data to flight and crash?		
		38. Checked pilot and aerodynamic control positions as necessary?		
		39. Photographic coverage checked with photographer?		
		IV. DETAILED SPECIFICS		
		40. Instrument panel.		
		a. Photographed?		
		b. Sketched?		
		c. Pertinent readings re-		

Applicable	Inapplicable	Question	Yes	No
		corded and compared?		
		d. Analysis given, if significant?		
		e. Damage areas depicted and described?		
		f. Other?		
		41. Cockpit and or cabin area?		
		a. Photographed?		
		b. Condition described (general)?		
		c. Safety belt and shoulder harness use noted?		
		d. Condition of items in *c* noted? Buckles? Webbing? End attachments? Etc.		
		e. Seat conditions noted? Security? Deformations, if any? Etc.		
		f. Causes of injuries, if any, found? Described, UER necessary or advisable? Etc.		
		g. Special equipment, if any, noted, etc?		
		h. Luggage, briefcase, etc., security noted?		
		i. Flight log, maps, map markings, etc., checked?		
		j. Condition of floor, walls, ceiling, fire exits, windshield, locks, brackets, covers, etc., checked?		
		k. Lighting equipment if appropriate, checked?		
		l. Other?		
		42. Pilot controls and setting.		
		a. Control positions noted, related, etc.?		
		b. Radio equipment settings noted? Condition of? Use of? Etc.		
		c. Automatic controls used?		
		d. Position of flaps noted?		
		e. Other?		
		43. Aerodynamic controls?		
		a. Positions, if pertinent, noted and photographed?		
		b. Damage? Relationship in the accident?		
		c. Relationship to pilot controls and settings?		
		d. Other?		
		44. Structural failure.		
		a. Determined as in-flight?		
		b. Causes of in-flight struc-		

Applicable	Inapplicable	Question	Yes	No
		tural failure determined?		
		c. Impact failures excessive in terms of occupant safety?		
		d. Characteristics of primary in-flight structural failure noted?		
		e. Structural failures of materials after impact characterized?		
		f. Other?		
		45. Other safety features and equipment.		
		a. Structures allowed reasonable safety for cabin occupants, without excessive breakage? With reasonable absorption of impact forces?		
		b. Redesign of some feature or piece of equipment for greater safety is considered essential?		
		c. Pilot vision clearance adequate?		
		d. Oxygen equipment, if used, satisfactory?		
		e. Special attention paid to safety design of seats, "platform" flooring holding seats, height, cushions, injury potentials thereon, etc.?		
		f. Special attention paid to safety design of instrument controls (knobs, switches, etc.) for pilot ease of use and delethalization: appropriateness of locations, materials used in manufacture, strength, elasticity, and absorption qualities, etc.?		
		g. Loose objects?		
		h. Other?		
		46. Malfunctioning or failure of equipment.		
		a. Determined as preimpact?		
		b. Cause discovered?		
		c. UER needed and made?		
		d Result (analysis) made?		
		e. Maintenance record and history checked?		
		f. Maintenance personnel, if appropriate, questioned?		
		g. System failure checked throughout? Checked with possible relationship to failures in other systems?		
		h. Help of specialist(s) needed? Obtained?		
		i. Tech reps called on?		
		j. Civilian aid (chemist, metallurgist, etc.) obtained?		
		k. Cause factors of malfunctioning and/or failure of equipment ascertained?		
		l. Other?		
		47. Airframe damage.		
		a. Preimpact and impact distinctions?		
		b. Any parts or pieces missing?		
		c. Extraneous articles (special equipment, etc.) involved?		
		d. Examined metal, wood, fabric, joints, laminations, etc.?		
		e. Other?		
		48. Landing gear.		
		a. In normal position for landing?		
		b. Malfunctioning parts?		
		c. Proper absorption quality?		
		d. Other?		
		49. Engine and engine installations and transmissions.		
		a. Damage checked in terms of structural and operational?		
		b. Faults checked in terms of structural and operational?		
		c. Evidence in relation to witness statements (smoke, flame, etc.) considered?		
		d. Evidence in relation to icing potentials considered?		
		e. Linkage, connections, breakage, etc., looked for?		
		f. Fuel and oil checked? Fuel supply? See item 51.		
		g. Carburetor checked?		

Applicable	Inapplicable	Question	Yes	No
		(Water, foreign matter, functioning, etc.)		
		h. Cooling, baffles, shafts, sumps, extensions, mounting, gears, vents, covers, etc., checked?		
		i. Other?		
		50. Propellers or rotor-blades.		
		a. Structural and operational checks?		
		b. All parts and pieces found?		
		c. Characteristic markings, bending, directions, etc., analyzed?		
		d. Checked related mechanisms or parts?		
		e. Noted make, model, type, and dimensions?		
		f. Noted total time of use, time since last overhaul, and similar maintenance forms data?		
		g. Measured distance between propeller ground marks?		
		h. Other?		
		51. Fuel and fuel systems.		
		a. Checked cocks, lines, obstructions, shavings, grade of fuel in use, filter, gauzes for deposits, signs of corrosions, etc.?		
		b. Was fuel system checked prior to flight?		
		c. If fuel grade below standards, checked condition of spark plugs, pistons, and cylinders?		
		d. Other?		
		52. Oil and oil system (failures, faults, quality, quantity, etc.) checked in similar manner as in item 50?		
		53. Electrical and hydraulic systems.		
		a. If failure discovered, noted type, model, serial number, and manufacturer of part which failed?		
		b. If engine failure indicated, checked spark plugs, spindles, insulators, shielding, harness, wires, etc.?		
		c. Tested spark plugs and/or magnetos?		
		d. Checked battery system?		
		e. If hydraulic system failure, checked all its parts, actuators, alignments, etc.?		
		f. Other?		
		54. If pertinent, heating and ventilating systems checked?		
		55. Radio transmitter, receiver, loudspeaker, amplifier, and other parts of communication system checked?		
		56. Considered lighting system(s) involvement in accident causes? Checked all parts?		
		57. "Go Right—No Go" criteria requirements for UER?		
		58. Sequence of accident events.		
		a. Determined?		
		b. Exhibited (photography, sketch, etc.)?		
		c. Proved?		
		59. Degree of material damage (repair or replacement cost) noted?		
		60. Injury.		
		a. Medical reports completed and included for finalized report?		
		b. Causes of each injury determined?		
		c. Autopsy report included for the deceased?		
		d. Preaccident human factors checked?		
		e. Other?		
		61. G force during impact(s).		
		a. Calculated?		
		b. Related to material damage?		
		c. Related to injuries?		
		d. Other?		
		62. Occupant location-attitude. Seating diagram necessary to accurately depict positions as related to material damage and resulting injuries?		
		63. Pilot's.		
		a. Flight time record secured? This type of aircraft? Last month? Last		

Applicable	Inapplicable	Question	Yes	No
		24 hours? Instrument? Etc.		
		b. Mission capability analyzed?		
		c. Training history, if appropriate, checked?		
		d. Mental aptitude, attitude toward flying, emotional tone, and other human factors checked, if appropriate? (Personal, family, etc.)		
		e. Other?		
		64. Witness information.		
		a. Complete?		
		b. Testimony analyzed and related to accident events and evidence?		
		c. Useless testimony omitted from finalized report?		
		d. Other?		
		65. Flight operations.		
		a. Personnel questioned, if appropriate?		
		b. Pilot flight planning checked?		
		c. Pilot attitude, conduct, etc., checked?		
		d. Radio messages sent, received, attempted, etc., checked?		
		e. Landing and/or takeoff indications, technique, etc., checked if pertinent?		
		f. Other?		
		66. Other supervision.		
		a. Medical supervision adequate?		
		b. Command supervision adequate?		
		c. Other?		
		67. Photography.		
		a. Wholly adequate, clear, orderly, captioned?		
		b. Emphasis techniques used as essential to clarity?		
		c. Other?		
		68. Samples.		
		a. Noted with suspense-date time, with person or agency handling, etc.?		
		b. Sample reports included in accident report?		

Applicable	Inapplicable	Question	Yes	No
		c. Other?		
		69. Charts and sketches.		
		a. Adequate?		
		c. Appropriate? (Best media choice.)		
		c. Master sketch details completed in all respects?		
		d. Other?		
		70. Wreckage released to salvage crew?		
		71. DA Form 285.		
		a. Requirements carefully checked against regulations:		
		b. All data accurate, complete, concise, clear?		
		c. Material damage degree and injury degree (with occupant attitude-location) notations made? Acurate?		
		d. Other?		
		72. Finalized report.		
		a. Well-organized?		
		b. Textual and illustrative data on opposite sides of the report folder for easy cross-reference?		
		c. Excess wordage, useless witness statements, pointless photographs, etc., deleted?		
		d. Supplementary details not to be included in the report filed in the event some detail may be requested at a later date? (For example, Board minutes.)		
		e. All parts of the report complete or, if not, a statement of explanation and date the additional data will be submitted?		
		f. Medical reports to cover each and every person injured in the accident? Autopsy report for any deceased person also included?		
		g. All required signatures?		
		h. Other?		

APPENDIX B

FLIGHT SEGMENT ANALYSIS
H-34A Helicopter

FLIGHT PHASES:

a. Normal Vertical Take-off

b. Climb

c. Cruise

d. Cruising Descent

e. Normal Approach

f. Normal Vertical Landing

Note: Tasks are coded as follows:

CR = Cruise
ACR = 1st Task in Cruise
BCR = 2nd Task in Cruise, etc.

Legend:

x = Activities and senses that are directly involved.

S = Activities and senses that are simultaneously involved (continuous scan of instruments, radio communication, intercom., sound of engine performance, etc.)

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Vertical Takeoff

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
A Release Parking Brakes	(1) depress left toe brake pedal (2) depress right toe brake pedal (parking brake handle moves into OFF position)	2				x	x		S	S	S				x	x	x			S	
B Prepare Tail Wheel to Swivel	(1) depress protruding button in center of tail wheel lock handle grip (2) push handle forward (tail wheel becomes unlocked)	5	7		x				x		S				x	x	x			S	
C Check Swiveling Condition of Tail Wheel	(1) depress left pedal (2) depress right pedal (3) depress left pedal (4) depress right pedal (small turns are made to ascertain that the tail wheel is unlocked)	8	15			x	x		x		S				x	x	x	x		S	
D Ascertain that Collective Pitch is at the Minimum	(1) push collective pitch lever downward to its lowest position	2	17	x					x		S				x	x	x			S	
E Secure Permission for Starting Take-Off	(1) depress microphone switch on cyclic stick handle grip (2) request clearance from tower to take-off* (taxi to strip, recheck that tail wheel swivel is locked) *If inapplicable, see Task K	10	27		x			x	x		S				x					x	

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Vertical Takeoff (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
F Secure Established Operating RPM	(1) rotate throttle grip steadily outward, downward, and to the left (2) depress left pedal to over-come the torque (3) observe RPM display	5	32	x		x			x	x	S					x	x			S	
G Raise Helicopter Verti-cally to Height Which Breaks Ground Contact (Customarily about 5 ft.)	(1) pull collective pitch lever upward to increase pitch (2) observe manifold pressure guage (3) observe RPM indicator	6	38	x					x	x	S				x	x	x	x		S	
H Check Operation of Flight Controls	(1) depress left and right pedals (2) manipulate collective pitch lever (3) test operation of throttle (4) evaluate cyclic stick adjust-ments	10	48	x	x	x	x		x						x	x	x	x		x	
I Check Operation of Flight Instruments and Engine Displays	(1) observe a. dual tachometer b. manifold pressure guage c. altimeter d. attitude indicator e. airspeed indicator f. vertical (airspeed) velocity indicator g. turn and bank indicator h. gyro compass (2) decide whether the displays and indicators are properly representing the engine and flight conditions	16	64						x	x										x	

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Vertical Takeoff (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	[illegible]	Muscle				
J Perform Power Check	(1) determine whether manifold pressure meets engine power check chart specifications (2) determine whether RPM meets engine power check chart specifications	4	68						x	x	S									S	
K Make Clearing Turn (if no Airport Tower is Available to Clear Helicopter for Take-Off)	(1) depress left pedal (2) observe area on all sides for approaching aircraft or other obstacles (3) decide when area is clear for take-off	10	78			x			x	x	S				x	x	x			x	

Legend:

x   Activities and senses that are directly involved.

S   Activities and senses that are simultaneously involved (continuous scan of instruments, radio communication, intercom, sound of engine performance, etc.)

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Climb

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
ACL Attain Safe Climb Speed	(1) maintain constant RPM (2) adjust pitch to reach safe autorotative climb speed (beyond the minimum of translational lift) (3) adjust throttle until 60 knots airspeed is attained (4) observe airspeed indicator	8		x	x	x	x		x	x					x	x	x	x		x	
BCL Recognize Attainment of Desired Cruising Altitude	(1) observe altimeter reading (2) decide whether the desired altitude is shown on the display	4	12						x	x	S									x	
CCL Reduce to Required Power	(1) decrease collective pitch (2) decrease manifold pressure from 40 to 35 inches (3) decrease RPM to amount specified for cruise under particular flight conditions and weight of helicopter	10	22	x	x		x		x	x										x	

Code:

x - activities and senses that are directly involved.

S - activities and senses that are simultaneously involved (continuous scan of instruments, radio communication, intercom, sound of engine performance, etc.)

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Cruise

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cum.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
ACR Place Helicopter in Cruising Attitude	(1) adjust position of cyclic stick (2) adjust collective pitch lever (3) adjust throttle (4) adjust pedal to overcome torque (5) observe attitude display	10		x	x	x	x		x		S				x	x	x			x	
BCR Place Mixture Lever Control into Normal Position	(1) move lever rearward to middle position	2	12	x					x		S				x	x	x			x	
CCR Adjust Carburetor Air Lever	(1) check carburetor air temperature guage (2) depress trigger on air carburetor lever (3) move lever to that temperature which will keep ice from forming in carburetor	6	18	x					x	x					x	x	x			x	
DCR Cross Check Instruments	(1) observe RPM display (2) observe manifold pressure (3) observe altimeter (4) observe attitude display (5) observe gyro compass (6) observe turn and bank (7) observe air speed display (8) observe rate of climb display (9) observe fuel quantity guage (10) repeat (1—9) as necessary	18	36						x	x	S									x	

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Cruise (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	L. L	Muscle				
ECR Monitor Radio Communication	(1) receives information through earphones (2) intermittently receives instrument flight instructions (3) selects desired radio frequency	contin-uous		x	x			x			x				x					x	
FCR Uses All Controls	(1) maintains altitude (2) adjusts power (3) maintains airspeed	contin-uous		x	x	x	x		x		S				x	x	x			x	
GCR Monitor Engine Instruments	(1) observe dual tachometer (2) observe manifold pressure guage (3) observe fuel pressure guage (4) observe fuel quantity guage (5) observe transmission temperature guage (6) observe transmission oil pressure guage (7) observe primary servo hydraulic pressure guage (8) observe position of fuel quantity selector switch (9) observe engine oil pressure guage (10) observe engine oil temperature guage (11) observe cylinder head temperature guage (12) observe carburetor air temperature guage (cont'd next page)																				

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Cruise (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
GCR (Cont'd)	(13) observe auxiliary servo hydraulic pressure guage (14) observe voltmeter (15) repeat (1—14) as necessary	30	66						x	x	S									x	
HCR Ascertain Fuel Situation	(1) observe that fuel flow selector handle is placed in the ON position (2) a. if fuel remains in aft tank, place fuel transfer pump switch in the aft position OR b. place fuel transfer pump switch in OFF position if aft is empty (3) if aft tank is empty and fuel remains in center tank, place center transfer pump switch in CTR position OR place CTP switch in OFF position if center tank is empty	4	70*	x					x		S				x	x	x			x	
	*NOTE: some tasks are repeated continually during cruise, others are performed simultaneously. The times required for repetitious or simultaneous actions are not included in this total.																				

LEGEND:

x - activities and senses that are directly involved.

S - Activities and senses that are simultaneously involved (monitoring instruments, radio communication, intercom, sound of engine performance, etc.)

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Cruising Descent

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & LOCO.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
ADE Move Mixture Lever into Rich Position	(1) observe position of mixture lever (2) place left hand on mixture lever (3) move lever forward until it comes to a stop	6		x					x		S				x	x	x			x	
BDE Reduce Collective Pitch	(1) place left hand on collective pitch lever (2) lower collective pitch lever (3) observe airspeed	6	12	x					x	x	S				x	x	x	x		S	
CDE Place Throttle into Reduced Operating Position	(1) rotate throttle inwardly (2) observe RPM display (3) adjust throttle to maintain desired rate of descent (4) depress right pedal to compensate for torque created by decreasing throttle action (5) observe attitude display	10	22	x			x		x	x	S				x		x	x		S	
DDE Alert Crew	(1) depress microphone switch for intercom communications (2) inform crew to prepare for deplaning	10	32		x			x							x		x			S	
EDE Observe Carburetor Temperature Guage	(1) ascertain whether carburetor air temperature is normal (2) if necessary, adjust carburetor air lever to maintain normal carburetor air temperature	4	36	x					x	x	S				x	x	x			S	

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Cruising Descent (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
FDE Ascertain that Parking Brake Handle is Placed in the Unlocked Position	(1) observe position of parking brake handle (2) depress brake pedals to release brake handle if it is locked	6	42			x	x		x		S				x	x	x			x	
GDE Place Tail Wheel Lock Handle in Prescribed Position for Specific Type of Terrain and Landing Procedure	(1) observe position of T.W.L. handle (2) perform either A or B A. (for running or autorotative landings and when landing on rough, furrowed, or rocky terrain) pull T.W.L. handle out to locked position B. (for normal vertical landing on smooth or level terrain) (1) depress button in center of handle to release ratchet-type lock (2) push T.W.L. handle forward horizontally to unlock tail wheel for swiveling	4 (6)	46	x					x		S				x	x	x			x	
HDE Place Carburetor Air Lever in Direct Position	(1) observe position of carburetor air lever (2) place left hand on C.A. lever (3) push C.A. lever forward until movement is stopped	6	52	x					x		S				x	x	x			x	

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Cruising Descent (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
IDE Turn Cabin Heater OFF	(1) locate cabin heater switch on overhead panel (2) observe position of switch (3) move heater toggle switch from High or Low to the center (OFF) position	6	58	x					x		S				x	x	x			x	
IDE Ascertain Position of Fuel Booster Pump Switch	(1) locate fuel booster pump switch (2) observe position of toggle switch	4	62						x		S									x	
	(3) move toggle switch upward to fuel BSTR pump position, if toggle switch is not presently placed there	(2)		x					x		S				x	x	x			x	
KDE Continue Descent	(1) continue to reduce collective pitch (2) continue to reduce throttle speed (3) depress right pedal to overcome torque (4) continue to adjust cyclic stick to conform with selected angle of descent (5) ascertain that RPM display indicates 2500 RPM (6) ascertain that airspeed indicator reflects attainment of 60 knots for entering approach phase of flight	12	74	x	x		x		x	x	S				x	x	x	x		x	

Legend:

x - Activities and senses that are directly involved.

S - Activities and senses that are simultaneously involved (continuous scan of instruments, radio communication, intercom, sound of engine performance, etc.)

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Approach

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
AAP Establish a Constant Approach Angle of About 30 Degrees at a Minimum of 60 Knots	(1) continue to reduce collective pitch (2) continue to reduce throttle speed (3) depress right pedal to overcome torque (4) observe attitude display (5) observe airspeed display (6) adjust cyclic stick to conform with angle of descent	12		x	x		x		x	x	S				x	x	x	x		x	
BAP Gradually Decrease Airspeed	(1) observe airspeed display (2) continue to reduce collective pitch (3) continue to reduce throttle action (4) continue to depress right pedal to correct for torque (5) below the 60 knot airspeed, pull back cyclic stick gradually to maintain angle of descent (6) observe attitude display (7) observe altitude display	14	26	x	x		x		x	x	S				x	x	x	x		x	
CAP Continue to Correct Approach for Under-Shooting or Overshooting of the Landing Site	(1) increase or decrease throttle slightly as needed (2) increase or decrease collective pitch slightly as needed (3) increase or decrease backward movement of cyclic stick as needed (cont'd on next page)																				

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Approach (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
CAP (Cont'd)	(4) observe altimeter (5) observe airspeed indicator (6) observe attitude display (7) observe RPM display to ascertain 2500 RPM engine speed (8) observe landing site (VFR) (9) repeat (1—8) as necessary	16	42	x	x		x		x	x	S				x	x	x	x		x	
DAP Attain Hovering Attitude	(1) increase collective pitch (2) increase throttle action (3) depress left pedal for torque control (4) terminate airspeed (5) descend to hovering attitude below 10 feet altitude (6) use rudder pedals to negotiate turns, or keep constant heading (7) retain sufficiently high altitude to prevent wheels from scuffing ground	14	56	x	x	x	x		x	x	S				x	x	x	x		x	

Legend:

x - Activities and senses that are directly involved.

S - Activities and senses that are simultaneously involved (continuous scan of instruments, radio communication, intercom, sound of engine performance, etc.)

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Vertical Landing

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSE				KINESTHETIC SENSE		BAL. & [illegible]	[illegible]	DISORIENTATION	OTHER [illegible]
		[illegible]	[illegible]	L	R	L	R		[illegible]	[illegible]		H	C	P	T	[illegible]	[illegible]				
ALA Descend Vertically for Touchdown	(1) manipulate rudder pedals to maintain constant heading (2) adjust position of cyclic stick to maintain level attitude (3) ascertain by observing RPM display that engine RPM are maintained at 2500 minimum (4) decrease collective pitch (5) observe landing area situation	10		x	x	x	x		x	x	S				x	x	x	x		x	
BLA Complete Landing Procedure	(1) ascertain that ground contact is made (2) reduce collective pitch nearly to its minimum (3) allow helicopter to settle on its oleo struts as rapidly as feasible (4) ascertain whether ground resonance is encountered a. if ground resonance is absent: (1) maintain 2400–2500 RPM for taxiing, OR (2) reduce engine RPM for engine shutdown	10	20	x					x	x	S				x	x	x	x		x	

Continued on next page

FLIGHT SEGMENT ANALYSIS

H-34A HELICOPTER

Normal Vertical Landing (Cont'd)

TASK	ELEMENTS	TOTAL TIME (Seconds)		HAND		FOOT		SPEAKS	LOOKS		HEARS	SKIN SENSES				KINESTHETIC SENSE		BAL. & EQUIL.	SMELL	DISCRIMI-NATION	OTHER (List)
		Unit	Cumul.	L	R	L	R		B-W	Color		H	C	P	T	Limb	Muscle				
BLA (Cont'd)	b. if ground resonance is present, before reduction of engine RPM,																				
	(1) increase collective pitch																				
	(2) take-off	12	32	x	x	x					S				x	x	x	x		x	
	c. after reduction of engine RPM																				
	(1) reduce collective pitch																				
	(2) reduce throttle																				
	(3) apply rotor brakes																				
	(4) apply wheel brakes	18	50	x	x	x	x				S				x	x	x	x		x	

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APPENDIX C

STATISTICAL RESULTS OF THE ACCIDENT STUDY

C.1 This appendix contains the statistical data obtained from the 1660 CAB accident reports.

C.2 Tables C.1-C.9. The accidents in each phase of flight are categorized by the type of accident and by the pilot's experience. The columns headed "N" refer to the total number of accidents for each time period; the columns headed "W" refer to those of the total accidents in which weather was a factor. For the phases of flight in which terrain is significant, there are separate tables for accidents occurring on runways and for accidents occurring on other terrain. For each phase of flight there is a table of "Time in Type" and a table of "Total Time".

C.3 Table C.10. Accidents for each phase of flight are listed by the percentage that occurred within each interval of pilot's time.

C.4 Table C.11. The number of accidents in each phase of flight is divided into categories showing the total number for each wing type, for each landing gear type, and for each plane manufacturer.

C.5 Index to Tables.

TABLE C.1

TOTAL NUMBER OF LANDING ACCIDENTS BY TIME IN TYPE AND ACCIDENT

1a. LANDING ACCIDENTS ON RUNWAY

Time in Type (Hours)	Collision Airplane	Collision Terrain		Collision Wires, etc.		Spin-Stall		Fire	Ground Loop		Hard Landing		Wheels up Landing		Over-Shot		Under-Shot		Nose up, Nose over		Nose Gear Failure		Miscel-laneous		Airplane Failure
	N	N	W	N	W	N	W	N	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	
50	3	5	5	20	4	5	3	1	69	28	34	4	27		29		26		44	22	25	3	3	3	
100	0	3		7	6	2		0	8	4	8	1	14		7	1	4		8	7	3		1		
200	0	2	1	4		1		0	7	3	3	1	6		5		2		3	3	2	1			
300	0	0		2		0		0	4	2	2	1	11		3	1	2		2	2	1				
500	1	0		1		0		0	3	1	2	1	7		4		2		1	1	1				
750	0	0		2	2	0		0	1		1	1	4		4	4	1		1		1				
1000	0	1		1	1	0		0	2		0		7		1		0		0		0				
1500	1	0		0		0		0	1		2	1	3		0		1	1	1	1	1				
2000	0	0		0		0		0	0		0		1		0		0		1		0		1		
2000+	1	0		0		0		0	1		0		1		1		0		4	1	1		0		
Unknown	0	1		0		0		0	3	1	3		0		1		2		0		0		1		
Totals	6	12		37		8		1	99		55		81		55		40		65		35		6		117

1b. LANDING ACCIDENTS ON OTHER TERRAIN

Time in Type (Hours)	Collision Airplane	Collision Terrain		Collision Wires, etc.		Spin-Stall		Fire	Ground Loop		Hard Landing		Wheels up Landing		Over-Shot		Under-Shot		Nose up, Nose over		Nose Gear Failure		Miscel-laneous		Airplane Failure
	N	N	W	N	W	N	W	N	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	
50	0	3	1	31	5	3	1	0	3		11	2	5	1	3	1	3		47	17	21	5	2	1	
100	0	2	2	9	1	1		0	1		2	1	0		4	1	1		13	2	9	1	1	1	
200	0	1	1	8	2	1		0	0		5	3	2		2		0		10	2	6	1	0		
300	0	0		4	2	0		0	1		3		1		2		0		1		2	2	1		
500	0	1		3		0		0	2		1		3	1	2	1	0		2		2		0		
750	0	1		3		0		0	0		0		1		0		0		3	1	1		0		
1000	0	0		2		0		0	0		2		1		1		0		3		4		2		
1500	0	0		2		0		0	0		1		0		0		0		0		1		0	1	
2000	0	1		1		0		0	0		0		0		0		0		0		1	1	0		
2000+	0	0		2		0		0	0		2		0		1		0		2		0		0		
Unknown	0	1		0		0		0	0		0		0		0		0		0		1		0		
Totals	0	10		65		5		0	7		27		13		15		4		81		48		6		

N — The total number of accidents.
W — Those of the N accidents in which weather was considered a factor.

TABLE C.2

TOTAL NUMBER OF LANDING ACCIDENTS BY TOTAL TIME AND ACCIDENT

Total Time (Hours)	Collision Airplane		Collision Terrain		Collision Wires etc.		Spin Stall		Fire	Ground Loop		Hard Landing		Wheels up Landing		Over-Shot		Under Shot		Nose up, Nose over		Nose Gear Failure		Miscel-laneous		Airplane Failure	
	N	W	N	W	N	W	N	W	N	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W	N	W
2a. LANDING ACCIDENTS ON RUNWAY																											
100	3	2	5	5	16	5	3	3	0	42	16	25	2	7		19	4	15	2	26	15	15		3	1		
200	0		2	2	4	1	2		1	15	8	5		5		6		4		10	8	4	1	1			
300	0		0		3		1		0	9	4	4		5		4		4	1	7	2	5	2	0			
400	1		1	1	1		0		0	6	3	4	1	6		4	1	4		2	2	1	1	0			
500	0		1		1		1		0	2		3	1	4		2		0		1	1	1		0			
750	0		0		3		0		0	9	5	4	4	6		2		2		3	2	1		0			
1000	0		0		2	2	1	1	0	1		3		6		5	1	4		1		2	1	0			
1250	0		0		3	1	0		0	1		1		5		1		1		3	1	2		0			
1500	0		0		1		0		0	1		1		5		1		1		1		1		1			
2000	0		1		2	1	0		0	5	2	1	1	9		2	2	1		4	3	1		0			
3000	0		1		1		0		0	4		2	1	13		3		1		2	1	1		0			
5000	1		0		0		0		0	2	1	1	1	8		3	1	1		5		0		0			
5000 +	1		1		0		0		0	2		1		1		1		0		0		0		0			
Unknown	0		0		0		0		0	0		1		1		1		0		0		0		0			
Totals	6		12		37		8		1	99		55		81		55		40		65		35		6		117	
2b. LANDING ACCIDENTS ON OTHER TERRAIN																											
100			2	1	19	3	1	1	0	1		4	1	1		4		1		23	9	12	2	1			
200			2	2	10	1	1	1	0	0		7	3	0		2	1	0		23	5	9	2	0			
300			2		6		0		0	1		0		0		2		2		7	3	7	1	1			
400			1		5	1	1		0	1		3		1		2		1		2	1	1	1	1			
500			1	1	3	2	1		0	0		2		0		1		0		1	1	2	2	0			
750			0		6	1	0		0	0		1		1		1		0		9	1	2		1	1		
1000			0		3		0		0	1		3	1	1		1		0		3		1		0			
1250			1		3	2	1		0	1		1		2		0		0		3	1	1	1	0			
1500			0		2		0		0	0		0		3		0		0		1		4	2	0			
2000			1		1		0		0	0		1		0		1	1	0		2		5		0			
3000			0		2		0		0	0		3		1		0		0		2		2		0			
5000			0		1		0		0	0		1		0		0		0		2		1		1			
5000 +			0		4		0		0	2		1		3		1	1	0		3		1	1	1	1		
Unknown			0		0		0		0	0		0		0		0		0		0		0		0			
Totals			10		65		5		0	7		27		13		5		4		81		48		6			

N - The total number of accidents.
W - Those of the N accidents in which weather was considered a factor.

TABLE C.3

TOTAL NUMBER OF ACCIDENTS IN FLIGHT BY PILOT'S TIME AND ACCIDENT

Time In Type (hours)	Stall & Crash		Collision Terrain		Collision Wires, Etc.		Fire	Collision Airplane		Undetermined (missing)		Misc.	Airplane Failure
	N	W	N	W	N	W	N	N	W	N	W		
50	38	6	26	16	20	1	3	1		3			
100	9		13	6	7			1		1	1		
200	4		10	6	11	1							
300	2		6	2	5			1					
500	8		7	4	3	1						1	
750	1		3		5	2							
1000	2		6	3	1					1			
1500	2		2	1	3	1							
2000			1		1	1							
2000 +	2		1		10		1						
Unknown	9	1	15	9	5	2		2	1	5	3	1	
Totals	77		88		71		4	5		10		2	49
Total Time													
100	19	3	19	11	3		2			1			
200	8	2	7	5	6	1				1			
300	5	1	3	2	4	1		1					
400	3		6	1	5								
500	2		4	2	5	1		1		1			
750	7	1	8	7	4	1							
1000	6		3		3								
1250	5		9	6	2								
1500	-		2	2	6	1							
2000	4		3	1	5					1		1	
3000	3		5	1	6		1			1			
5000	9		4	2	12		1						
5000 +	2		8	2	10	1		1					
Unknown	4	1	7	4				2	1	5	3	1	
Totals	77		88		71		4	5		10		2	49

N — The total number of accidents.
W — Those of the N accidents in which weather was considered a factor.

TABLE C.4

TOTAL NUMBER OF ACCIDENTS DURING TAKE-OFF BY TIME IN TYPE AND ACCIDENT

4a. ACCIDENTS DURING TAKEOFF ON RUNWAY

Time in Type (Hours)	Collision Airplane	Collision Terrain		Collision wires, etc.		Spin Stall		Fire	Ground loop		Wheels up Landing	Nose-up Nose-over		Nose Gear Failure	Aborted Takeoff		Misc.	Airplane Failure
		N	W	N	W	N	W		N	W		N	W		N	W		
50		6	3	13	4	16	2		7	1		9		1	9	3		
100	1					2	1		2	1		3			2	1		
200				2	2	3	1				1	1	1		4	1	1	
300				[illegible]	1	2			1		1	3	1		1	1		
500				2	2	1			2	2					2	1		
750				1					1	1		1						
1000				1														
1500	1					1						1						
2000																		
2000 +		3				1												
Unknown		2									1	1						
Totals	2	11		22		26			13		3	19		1	18		1	16

4b. ACCIDENTS DURING TAKEOFF ON OTHER TERRAIN

Time in Type (Hours)	Collision Airplane	Collision Terrain N	Collision Terrain W	Collision wires, etc. N	Collision wires, etc. W	Spin Stall N	Spin Stall W	Fire	Ground loop N	Ground loop W	Wheels up Landing	Nose-up Nose-over N	Nose-up Nose-over W	Nose Gear Failure	Aborted Takeoff N	Aborted Takeoff W	Misc.	Airplane Failure
50		2		14	4	5		1	2			8	3	2	6		1	
100				3		1			1			2			3			
200		1	1	3	1							3		1	2			
300				2														
500		1		1		1												
750				1														
1000				2								2						
1500				2														
2000																		
2000 +									1									
Unknown																		
Totals		4		28		7		1	4			15		3	11		1	

N — The total number of accidents.
W — Those of the N accidents in which weather was considered a factor.

TABLE C.5

TOTAL NUMBER OF ACCIDENTS DURING TAKE-OFF BY TOTAL TIME AND ACCIDENT

5a. ACCIDENTS DURING TAKEOFF ON RUNWAY

Total Time (Hours)	Collision Airplane	Collision Terrain		Collision wires, etc.		Spin Stall		Fire	Ground loop		Wheels up Landing	Nose-up Nose-over		Nose Gear Failure	Aborted Takeoff		Misc.	Airplane Failure
		N	W	N	W	N	W		N	W		N	W		N	W		
100		5	3	4	2	2			1			5	2		4	1		
200		1		2	2	7	2					3	1	1	3			
300				6	1	3			2						2	1		
400				2		1			1	1		1			3	1		
500				1		1						2						
750	1			1	1	3						1			1			
1000				2	1	2	2		1		1	1	1					
1250				1		1			1						1			
1500						1												
2000				1		2			1	1		3	1					
3000	1			2					3	1		1	1		2		1	
5000		4				1			1	1	1				1			
5000 +		1				2			1	1	1	1			1	1		
Unknown									1			1						
Totals	2	11		22		26			13		3	19		1	18		1	16

5b. ACCIDENTS DURING TAKEOFF ON OTHER TERRAIN

Total Time (Hours)	Collision Airplane	Collision Terrain		Collision wires, etc.		Spin Stall		Fire	Ground loop		Wheels up Landing	Nose-up Nose-over		Nose Gear Failure	Aborted Takeoff		Misc.	Airplane Failure
		N	W	N	W	N	W		N	W		N	W		N	W		
100				5	3	2			1			6	2		2		1	
200				4		2			1			1			3	1		
300				4	1	1		1				1			1			
400		1		1					1						1			
500				1	1	1												
750		1	1	1								1	1					
1000				1								1			1			
1250		2												1	1			
1500						1						1		1				
2000				4								2		1				
3000				1								1						
5000				3											1			
5000 +				3	1				1			1			1			
Totals		4		28		7		1	4			15		3	11		1	

N — The total number of accidents.
W — Those of the N accidents in which weather was considered a factor.

TABLE C.6

TOTAL NUMBER OF TAXIING ACCIDENTS BY PILOT'S TIME AND ACCIDENT

Time in Type (Hours)	Collision Airplane	Collision Terrain	Collision Wires, etc		Ground loop		Nose-up Nose-over		Nose Gear Failure	Aborted Takeoff	Miscellaneous		Airplane Failure
			N	W	N	W	N	W			N	W	
50	5	2	10		2	2	19	2	5	1	4	1	
100			6				5	4	2				
200			8				6	3	1	1			
300			2	1			3	2					
500			5	2			2	1	2				
750	1	1	2						1				
1000			2										
1500			1						1				
2000	1												
2000 +													
Unknown	1						1		1				
Totals	8	3	36		2		36		13	2	4		6
Total Time													
100	4		7				16	10	3		3		
200	1		5				4	2	1				
300		1	2		1	1	5	1	1	1			
400			1				1						
500			6				2		1				
750			3				1	1	1	1			
1000			3										
1250			1				1	1					
1500	1		1				1	1	1				
2000			2	1	1	1	1		2				
3000	1		2	1			2	2					
5000		1	2	1			1		3				
5000 +	1	1	1				1	1			1	1	
Totals	8	3	36		2		36		13	2	4		6

N — The total number of accidents.
W — Those of the N accidents in which weather was considered a factor.

TABLE C 7

TOTAL NUMBER OF LANDING APPROACH ACCIDENTS
BY PILOT'S TIME AND ACCIDENT

Time in Type (Hours)	Collision - Terrain	Collision - Wires	Stall and Crash	Fire	Airplane Failure
50		23	20		
100		8	4	1	
200	1		4	1	
300		4	2		
500		3	3		
750		2			
1000		2			
1500		1	1		
2000					
2000 +					
Unknown		2			
Totals	1	45	34	2	3
Total Time (Hours)					
100		12	14		
200		7	5	1	
300		4	1		
400		1			
500		2	1		
750		7	1		
1000		4	3		
1250			2		
1500			1		
2000	1		3		
3000		4	1		
5000		1			
5000 +		2	2		
Unknown		1		1	
Totals	1	45	34	2	3

TABLE C.8

TOTAL NUMBER OF ACCIDENTS DURING GO-AROUND BY PILOT'S TIME AND ACCIDENT

Time in Type (Hours)	Stall & Crash	Collision Terrain	Collision Wires, etc	Ground Loop	Hard Landing	Wheels up Landing	Overshot	Nose Gear Failure	Airplane Failure
50	4	4	5	1					
100	1	2				1	1		
200	3	1	2		1				
300	1		1						
500		1					1		
750									
1000							1	1	
1500									
2000									
2000 +									
Unknown					1				
Totals	9	8	8	1	2	1	3	1	3
Total Time									
100	4	1	2						
200	3	3	3				1		
300	2	1							
400		1	1						
500		1	1						
750			1		1				
1000				1			2		
1250									
1500									
2000									
3000					1	1		1	
5000		1							
5000 +									
Unknown									
Totals	9	8	8	1	2	1	3	1	3

TABLE C.9

TOTAL NUMBER OF ACCIDENTS DURING STATIC PHASE BY PILOT'S TIME AND ACCIDENT

Time in Type (Hours)	Collision Airplane	Collision Other	Nose-up Nose over N	Nose-up Nose over W
50	1	1	2	2
100			1	1
200	2		1	1
300	1			
500				
750	1			
1000		1	1	1
1500			1	1
2000				
2000+				
Totals	5	2	6	
Total Time				
100	1	1	1	1
200				
300	1			
400				
500			2	2
750				
1000	1		1	1
1250			1	1
1500				
2000	1	1		
3000				
5000	1			
5000+			1	1
Totals	5	2	6	

N — The total number of accidents.
W — Those of the N accidents in which weather was considered a facto .

TABLE C.10

PER CENT OF ACCIDENTS BY PILOT'S TIME AND PHASE OF OPERATION

Time In Type (hours)	Landing (%)	Landing Approach (%)	In Flight (%)	Take-Off (%)	Taxiing (%)	Static (%)	Go Around (%)	Undetermined (missing)	Total (%)
50	51	51	36	51	45	31	49		47
100	14	15	11	11	14	8	14		13
200	11	11	10	11	14	22	17		11
300	5	7	5	8	5	8	8	Less	6
500	6	7	7	6	10	0	3	than	6
750	3	2	4	2	4	8	0	1%	3
1000	3	2	4	3	3	15	6		4
1500	2	2	3	2	1	8	0		3
2000	1	0	1	0	1	0	0		1
2000 +	2	0	6	3	0	0	0		2
Unknown	1	2	12	3	3	0	3		4
Total Per Cent	100	100	100	100	100	100	100		100
Total Time (hours)									
100	27	32	16	18	30	23	20		24
200	14	16	9	14	10	0	29		13
300	7	7	6	12	10	8	9		8
400	6	1	6	6	3	0	5		5
500	3	4	4	3	9	15	5	Less	4
750	7	9	7	6	5	0	5	than	7
1000	5	8	6	7	3	15	9	1%	6
1250	4	2	6	4	2	8	3		4
1500	3	1	3	2	4	0	0		3
2000	4	5	7	7	5	15	0		5
3000	5	6	6	6	5	0	9		6
5000	6	1	10	6	8	8	3		6
5000 +	7	5	8	6	5	8	0		7
Unknown	1	2	6	3	0	0	3		2
Total Per Cent	100	100	100	100	100	100	100		100

TABLE C.11

NUMBER OF ACCIDENTS BY PLANE, TYPE, AND PHASE OF OPERATION

	Landing				In Flight				Take-off				Landing Approach				Taxiing				Go Around				Static				Undetermined				
	Nose		Tail		Nose		Tail		Nose		Tail		Nose		Tail		Nose		Tail		Nose		Tail		Nose		Tail		Nose		Tail		Total
	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	HW	LW	Number
J	90	54	104		12	18	77		22	7	46		8	2	15		19	4	10			1	5		3		2		1		1		499
E	74	12	136	6	31	1	23		9	1	22		7	2	9		28		14		7		10		2		3		2				399
B		73	1			16				17	1	1		7				6				1				1				1			125
A	22		62				11		3		13		2		3		4		7		1		3				1				1		133
M	1		28	17			3	5			6	6			6	1			2	1			1										77
L			17				7				1				4				1				1								1		32
K			46				4				14				10				1														75
G		31				8				4				2								2											47
A			9				3				4				2				2				1										21
D	Bi-wing 16				Bi-wing 59				Bi-wing 8																								83
I		20				4		3		3				2				1				1											35
H		21				3				4				1				2															31
C				17				1				1																					19
Other	Bi-wing 5				Bi-wing 6				Bi-wing 5																								84
	7	5	11	12				11		1	2	5			3	1	1	2	1	4			1					1					
Sub-Totals	194	216	414	53	43	50	128	20	34	37	109	13	17	16	50	2	52	15	38	5	8	5	22		5	1	6	1	3	1	3		
	Bi-wing 21				Bi-wing 65				Bi-wing 13																								
Totals	898				306				206				85				110				35				13				7				1660

HW - High Wing
LW - Low Wing

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APPENDIX D

ORI TECHNICAL MEMORANDUM 112-60: INFLUENCE OF LANDING GEAR CONFIGURATION ON LIGHT PLANE LANDING ACCIDENTS

D.1 The results of the statistical analysis indicate that the frequency of landing accidents due to gear configuration is somewhat less for tail-wheel planes than for nosewheel planes; shown in Figures D.1, D.2, D.3 and Table D.1.

<u>Tailwheel Gear</u> —

$$\frac{\text{282 (number of accidents due to gear, out of 2310 accidents studied)}}{\text{40,623 (total number of active light planes with tailwheel gear)}} = 0.0069 \qquad \text{(144 planes/accident).}$$

<u>Nosewheel Gear</u> —

$$\frac{\text{190 (number of accidents due to gear, out of 2310 accidents studied)}}{\text{21,877 (total number of active light planes with nosewheel gear)}} = 0.0087 \qquad \text{(115 planes/accident).}$$

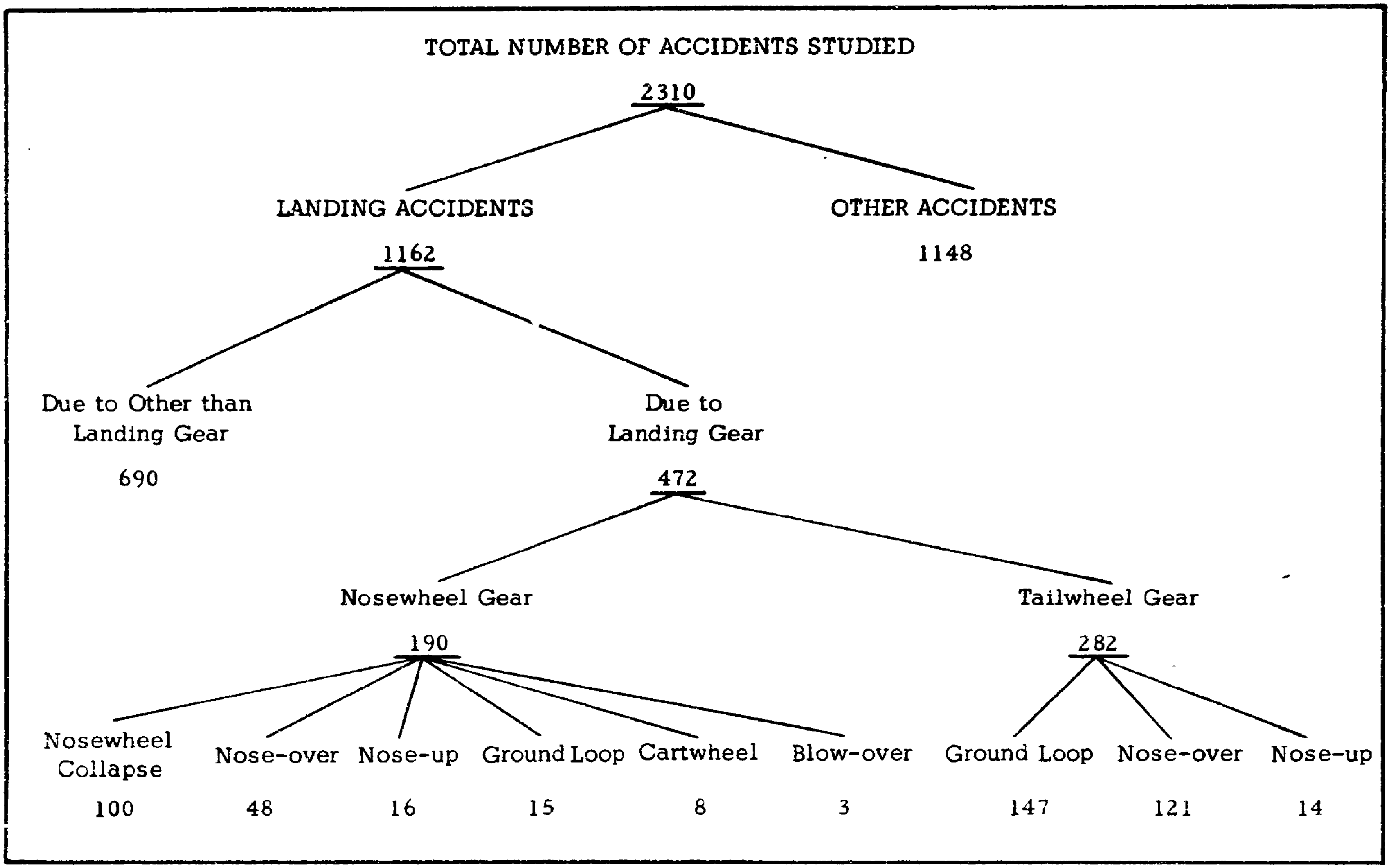
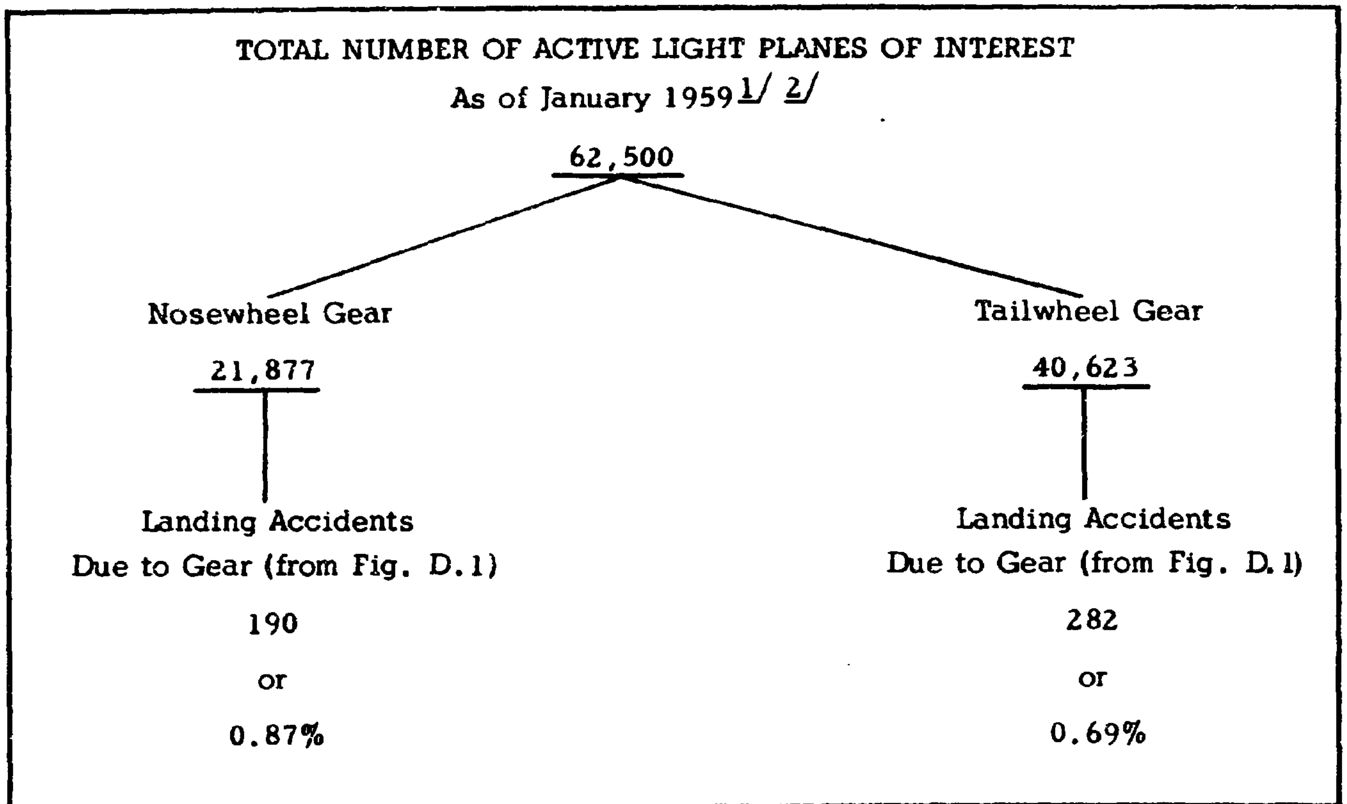


FIGURE D. 1. STUDY OF CIVIL AERONAUTICS BOARD ACCIDENTS REPORTS



1/ Federal Aviation Agency, Statistical Study of U. S. Civil Aircraft (1960).

2/ Federal Aviation Agency, Aircraft Specifications.

FIGURE D. 2 LANDING ACCIDENT FREQUENCY

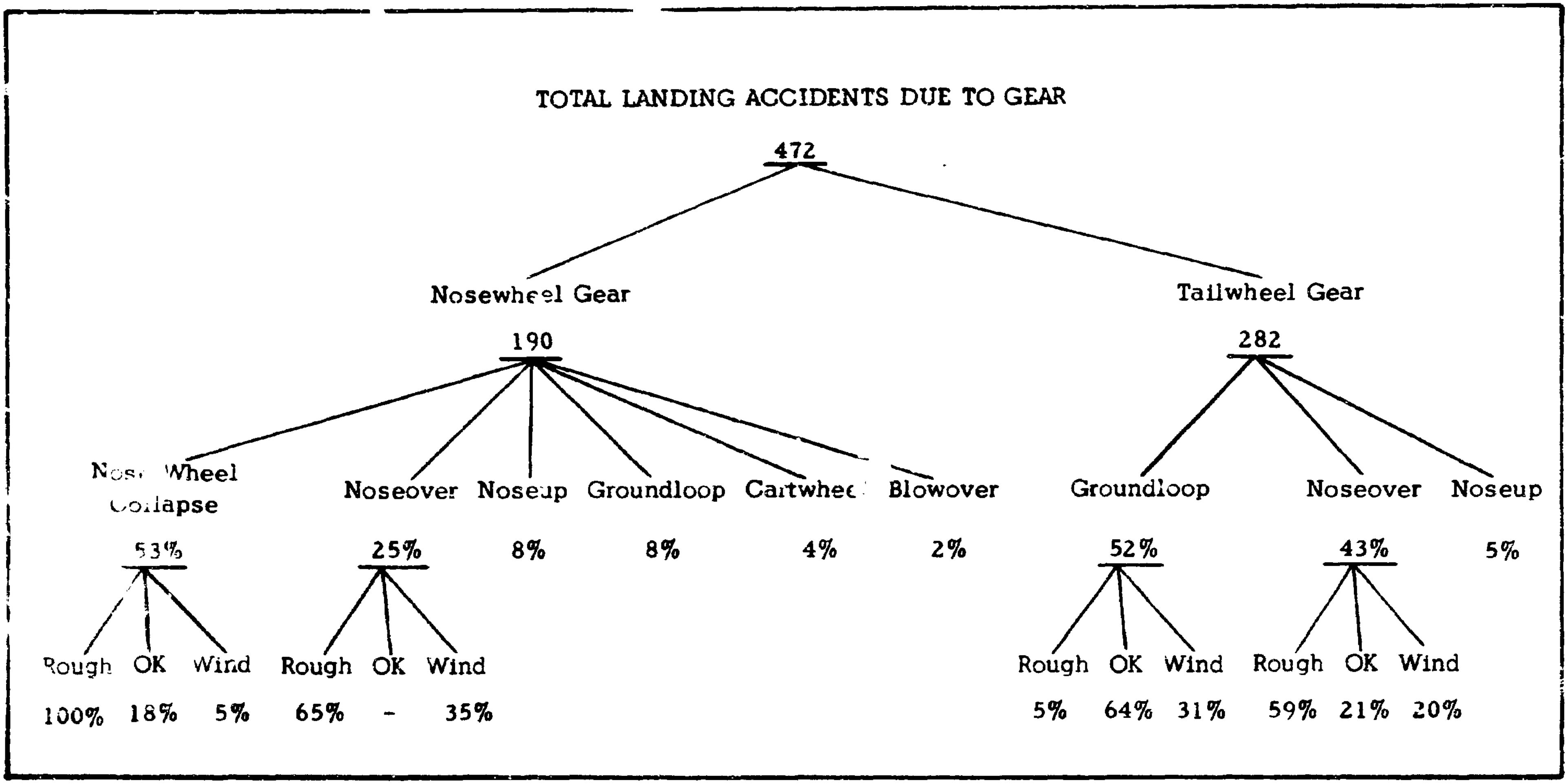


FIGURE D. 3. RELATIVE OCCURRENCE OF VARIOUS LANDING ACCIDENTS

TABLE D. 1

LANDING ACCIDENTS DUE TO GEAR FOR CERTAIN ACTIVE LIGHT PLANES, ORI STUDY-TM-112-60

Manufacturer	Number of Nosewheel Planes	Frequency of Landing Accidents Due to Gear* Per Cent	Number of Tailwheel Planes	Frequency of Landing Accidents Due to Gear* Per Cent
A	263	6.5	5568	0.7
B	4534	0.3	239	—
C	—	—	483	1.0
D	—	—	1981	0.4
E	6048	1.0	10396	1.0
F	—	—	496	1.2
G	2512	0.4	—	—
H	446	1.3	—	—
I	—	—	182	1.6
J	6487	1.2	10532	0.5
K	—	—	2592	1.4
L	—	—	2566	0.3
M	—	—	3938	1.1

*Frequency of Landing Accidents Due to Gear = $\dfrac{\text{Number of "X" airplanes involved in landing accidents due to gear}}{\text{Total number of "X" airplanes active in year of study}}$